THE MAGAZINE THAT FEEDS MINDS

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Why a bird's plumage is so essential to its survival

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ISSUE 050


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ISSUE 50

WELCOME

The magazine that feeds minds!

Page 42
We know what's on top of Antarctica, now find out what lies beneath…

The saying goes that necessity is the mother of invention and over the years humankind has constantly pushed the proverbial envelope to extend our creativity and innovation beyond the accepted boundaries of what is possible. Indeed the phrase 'pushing the envelope' itself refers to the exceeding of the flight envelope (that is, the safe limits of an aircraft's capabilities) and why going beyond those limits enables us to see what else might be achievable.

Since the dawn of time, the human mind has sought out creative solutions to universal problems in order to survive, develop and even help us enjoy our lives in the quest for advancement. In this issue's special feature we celebrate the creations that have stood the test of time… as well as smiling at the rather less-enduring contraptions that managed to find their way into production. Enjoy the issue.

Helen Porter
Editor

Meet the team…

Robert
Features Editor
Speaking to Richard Noble, former land speed record holder and now working on the Bloodhound SSC rocket car, was a pleasure.

Jackie
Research Editor
I was fascinated to learn about the methods of producing wireless electricity. Maybe one day we'll be free of all these pesky cables!

Marcus
Designer
I've loved learning about the inventions that helped shape the world. Often the things we take for granted are the most important.

Adam
Senior Sub Editor
Fracking has been in the news for some time now, so it was great to find out what this controversial mining technique is all about.

What's in store…

The huge amount of information in each issue of How It Works is organised into these key sections:

Science
Uncover the world's most amazing physics, chemistry and biology

Technology
Discover the inner workings of cool gadgets and engineering marvels

Transport
Everything from the fastest cars to the most advanced aircraft

Space
Learn about all things cosmic in the section that's truly out of this world

Environment
Explore the amazing natural wonders to be found on planet Earth

History
Step back in time and find out how things used to work in the past

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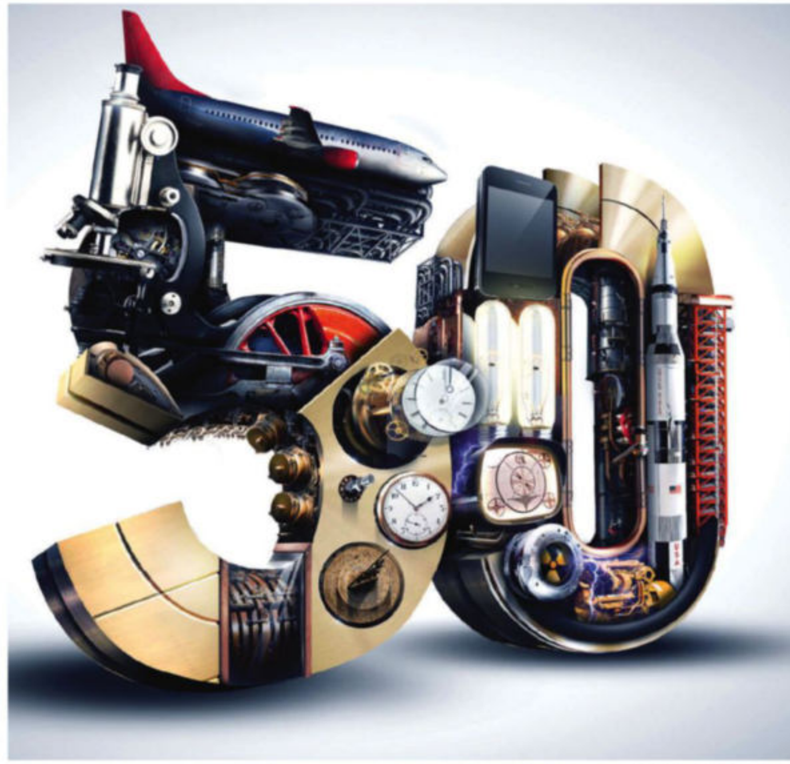
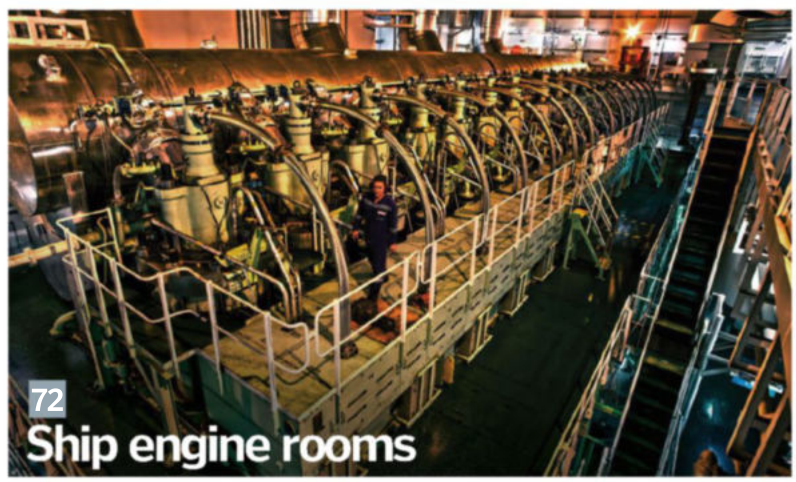




72 Ship engine rooms

Meet the experts…

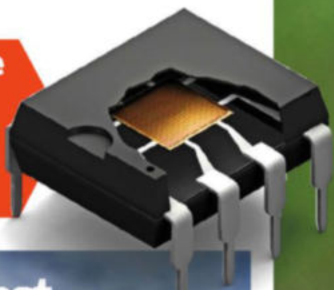
Tim Hopkinson-Ball
Brooklyn Bridge
Building buff Tim is back this issue to brief us all on the construction of one of the most iconic suspension bridges on the planet: the Brooklyn Bridge in New York, made in the late-19th century.

Giles Sparrow
Solar storms
An authority on the subject of space, author Giles set to work to explain the science of the solar cycle and why our technology on Earth can fall victim to the Sun's outbursts during the solar maximum.

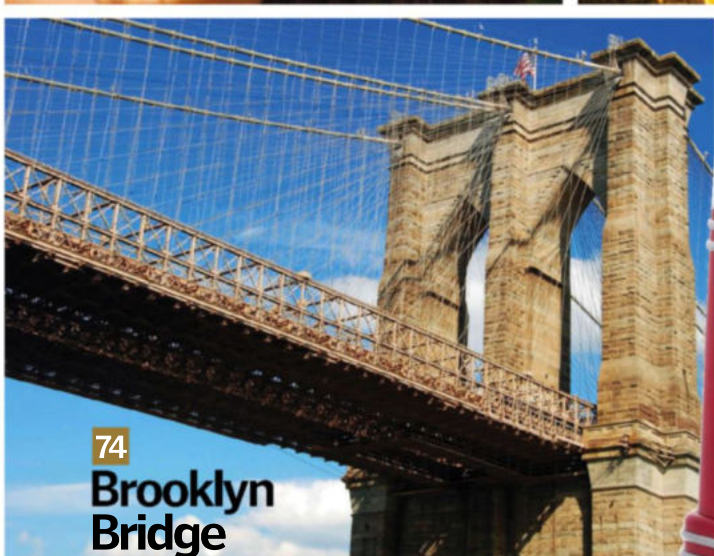
Luis Villazon
Deadliest places
Environment expert Luis goes to the ends of the Earth to reveal the most dangerous locations around, from a lake that's a gas bomb to a crystal cave that gets hotter than a desert.

Alexandra Cheung
Periodic table
This issue Alex helps us to comprehend the dozens of hugely varied elements that make up the periodic table as well as the way that they're organised.

Vivienne Raper
Under Antarctica
With some great contacts involved in the exploration of Lake Vostok, Vivienne is hot on the subject of Antarctica. Find out what's lying under all that ice over on page 42.



What's inside all electronic devices? Find out now on page 54



REGULARS

WIN!

All these prizes

See page 28 for details on how to enter our issue 50 giveaway

GLOBAL EYE
Showcasing the incredible world we live in

Flyboarding takes off

Flyboards enable thrill-seekers to soar through the air like a real-life Iron Man

The Flyboard, a revolutionary new way to get around that allows its rider to cruise and dive through the air as if using a jetpack, as well as underwater like a torpedo, is set to go mainstream, according to recent reports. With over 1,500 units now sold worldwide, the latest iteration of the system has received a technological overhaul that makes it both more accessible and powerful.

The Flyboard itself is similar to a wakeboard in construction, with the rider angling its orientation to change direction. Connected to the board, however, are two pipes that lead to a 186-kilowatt (250-horsepower) jet-ski turbine via long, flexible tubes. When this jet-ski turbine is turned on – which can be done by a second person or by the Flyboard operator themselves – water is drawn through the piping network at high pressure to propel the rider around ten metres (33 feet) above the water's surface, with a pair of hand cannons aiding stability.

Combined, these features allow the Flyboard's user to perform a variety of stunts, ranging from corkscrew barrel rolls to spectacular dives and swoops. Indeed, this extreme sport has become so popular that last year saw the first-ever Flyboard World Cup take place in Doha, Qatar, with riders from all around the world going head to head to compete in a wide variety of freestyle trick competitions.

France's David Goncalves competing at the inaugural Flyboard World Cup held in Qatar in 2012

Wolf howl decoded

A research team from Nottingham Trent University, UK, has developed a computer program that can analyse the vocal signatures of wolves and determine individuals by their howls. The program, which studies both howl volume and pitch, was trialled on eastern grey wolves in Algonquin Provincial Park, Canada, and returned a success rate of 100 per cent in recognising individuals and 97 per cent when identifying groups. Speaking on the findings published in the journal *Bioacoustics*, research leader Holly Root-Gutteridge said: "In scientific terms this is really exciting, because it means that if we hear a howl on one night we can tell if it is or isn't the same wolf that you hear on subsequent nights."

As to its applications, Root-Gutteridge said the program could be used by conservationists to monitor wolf pack populations and migration.

All About History needs you!

Have you got any letters, heirlooms or other antiques hidden in a cupboard? Or perhaps a fascinating family story that's been passed down the generations? If so, **All About History** wants to hear from you. The new title is looking for real-life artefacts, and in every issue it will showcase some of your amazing stories and snaps. What's more, the best contribution each month will win a digital film scanner to preserve your memories for the future. If you've got any tales you'd like to share, email **allabouthistory@imagine-publishing.co.uk**, or write to: All About History, Imagine Publishing Ltd, Richmond House, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ.

The need for speed

We talk to Richard Noble who held the world land speed record for 14 years and find out how the Bloodhound SSC project is revitalising British engineering

Tell us about the current status of the Bloodhound SSC project.
Where we are at the moment is the car build stage, which is an enormous process. We've just recently been through a re-plan of the entire programme to establish how quickly we can get the vehicle finished and we have realised that, by adding additional resources, we can complete the Bloodhound during quarter two of 2015. That's a year later than we hoped, but that is how these things go and we now have a great plan from which to move forward.

"With exposure to high-speed driving your mental processes speed right up so everything happens in super-slow motion"

How great a challenge is breaking the 1,000mph barrier on land?
It is the most enormous challenge and admittedly when we started this project we completely underestimated it. We have to produce a car that will outperform any jet fighter – we don't know any jet fighter that can do [1,609 kilometres] 1,000 miles per hour under [914 metres] 3,000 feet – and we are really just pushing the boundaries of what is possible.

And, of course, this is a very high-profile project and something you can't cut any corners on. You have to be absolutely focused on the engineering and, quite frankly, it has been an absolutely huge programme.

The reality is that it's the equivalent of creating a jet fighter and here we are with just 60 people and funding from sponsorship. But we are doing great and people are starting to realise that the Bloodhound is going to generate considerable global exposure.

What is it like to drive a supersonic car?
It's being a constituent part of a very tight-knit team, where everybody depends on everybody. The driver is just one role of many.

Of course, it is a very lonely job because, as soon as the cockpit cover is shut, you're on your own – and that worries the hell out of the engineers! There's a huge level of trust involved as you have to drive that car to the run profile that has been planned and you need to be incredibly accurate. It's a cold-blooded exercise and if the driver is getting some sort of buzz out of it then the team is in trouble. The cost of doing this is considerable, so [it's imperative] for you not to mess up.

From my point of view when driving the Thrust2, I was driving at over [966 kilometres] 600 miles per hour most days – indeed, I have driven over 600 miles per hour 11 times – as the Thrust2 was only just capable of breaking the record, but we got there in the end. After a bit it becomes almost an everyday activity – it's as simple as that. But what does happen is that with exposure to high-speed driving your mental processes speed right up so everything happens in super-slow motion; you have plenty of time to think your way through it.

How have land speed record attempts changed since your run in 1983?
Well, in the old days back in, say, the 1930s the teams weren't capable of modelling the cars and because they couldn't model them the driver was taking a tremendous risk. All the engineers could do was play an advisory role, just offering a few helpful words and, looking back on my experience in the Thrust2, I guess I was one of the last of those drivers who took a considerable risk just getting in the car.

Now things have changed. With the introduction of computational fluid dynamics (CFD), it's possible to accurately model the aerodynamics of the vehicle and this gives us a huge database and an enormous amount of data coming off the car. This really helps us to keep things on track and ultimately minimises the risk to everybody – to the driver, to the team and to the sponsors. So if you get a situation where the data coming off the car diverges substantially from the modelling data then you know you're in trouble and that is the point where the project stops.

The Bloodhound SSC project is involved in a lot of educational activities – was this always the plan?
Oh, it's absolutely vast. What is happening is that the UK is in really deep trouble at the moment because, according to the Royal Academy of Engineering, we need 830,000 new engineers by 2020 and we are producing only around 30,000 per year. So the education side of Bloodhound – which was an idea that came from Lord Paul Drayson – has become incredibly important. We now have 5,542 schools on the Bloodhound educational programme and it's growing at a massive rate.

In your opinion, what are the main benefits of building the Bloodhound and breaking the 1,000mph barrier?
Starting at the beginning with education, we've got over 5,500 schools on this thing now so we have a huge obligation to deliver this project successfully. There are a lot of new engineers being created [off the back of the Bloodhound]; in fact, two of the founding universities involved with the Bloodhound SSC project have seen their engineering intake double over the last three years.

The second thing is linked to the fact that we have developed a very, very expensive country to live in, where a high proportion of national expenditure goes on government projects and public services. The only way therefore for a country like the UK to actually *earn* money is through manufacturing, and we've let our manufacturing resource decline to about ten per cent of GDP.

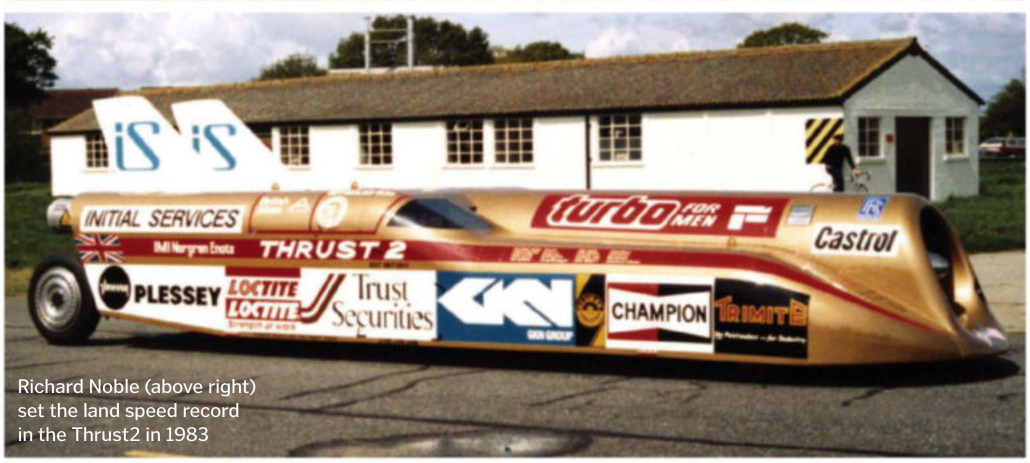
Lastly, in Britain there is a complete lack of confidence. The British haven't really done anything astonishing in engineering terms since Concorde so there's a need for something like the Bloodhound to uplift everything. I mean, when we broke the record for the second time in 1997 with the ThrustSSC, its website became the fifth largest in the world – that gives you an idea of what is possible here.

When does the Bloodhound hit the road?
We are going to be in South Africa in 2015 and the idea is to get the car supersonic then, which will be the curtain opener. We might even get a new world record that year. Then we will bring it back to Britain, sort it all out, before heading back to South Africa in 2016 to finish the project by exceeding 1,000 miles per hour.

For more on the Bloodhound and to discover how you can get your name on the car for just £10, visit www.bloodhoundssc.com.

The Bloodhound is set to break 1,609km/h (1,000mph) in 2016


Noble (right) with ThrustSSC driver, RAF wing commander Andy Green, in Nevada, USA



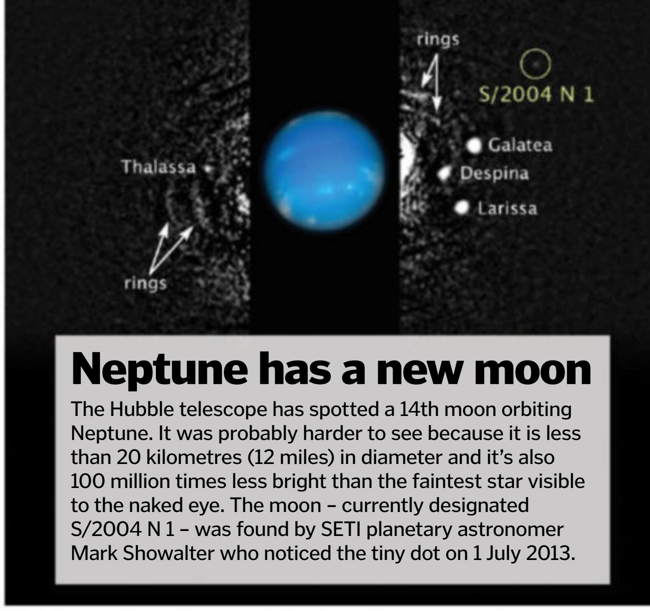
Richard Noble (above right) set the land speed record in the Thrust2 in 1983

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Bees greet with their antennae

Just like humans use both sides of their brain for different purposes, so too do honeybees. In fact, they prefer to use their right-hand antenna when determining the difference between friend and foe. Each antenna is covered in sensitive hairs called sensilla, which are the chemical receptors that send sensory information to the brain. The right antenna apparently features more sensilla that are concerned with the sense of smell, which is an important method of insect communication.



Neptune has a new moon

The Hubble telescope has spotted a 14th moon orbiting Neptune. It was probably harder to see because it is less than 20 kilometres (12 miles) in diameter and it's also 100 million times less bright than the faintest star visible to the naked eye. The moon – currently designated S/2004 N 1 – was found by SETI planetary astronomer Mark Showalter who noticed the tiny dot on 1 July 2013.

Gorilla Glass shrinks

The shrinking of Gorilla Glass (often used on smartphone screens) has been measured for the first time. Technicians at Corning, where the material is made, observed a sheet of the glass for 18 months. In the first ten days the glass's width and length decreased by five micrometres and, over 18 months, it shrunk by another five micrometres. It won't damage your phone, but the shrinkage is interesting. Atoms of sodium and potassium, which help make the glass robust, initially move around as if in liquid form until they find an energetically more favourable position and slow down.

20,000 Earthlings said, "Cheese!"

Using a wide-angle camera on 19 July NASA's Cassini space probe took some very cool snaps of the Earth from a distance of nearly 1.5 billion kilometres (900 million miles) away near Saturn. In this rare colour photograph, our planet and the Moon were captured in the same frame as the ringed gas giant. On the same day NASA's MESSENGER probe also acquired a black-and-white still of Earth from its orbit 98 million kilometres (61 million miles) away around Mercury. NASA informed the world the images were being captured on 19 July, giving Earth's inhabitants the chance to locate Saturn with their telescopes and wave. 20,000 people took part and shared their photos online.

TV dinners taste worse

A Dutch study, published in the journal *Psychological Science*, has revealed that our perception of how food tastes changes when we are engaged in other activities. Many of us eat on the go or while watching television, and it's thought that it's distractions like these that impair our taste perception. The intensity of sweetness and saltiness is reduced when we're not paying attention, which led the test subjects to add more salt and sugar to food than was necessary. Not only that, but we also pay less attention to how much food we're putting into our mouths, so we're less aware of being full.

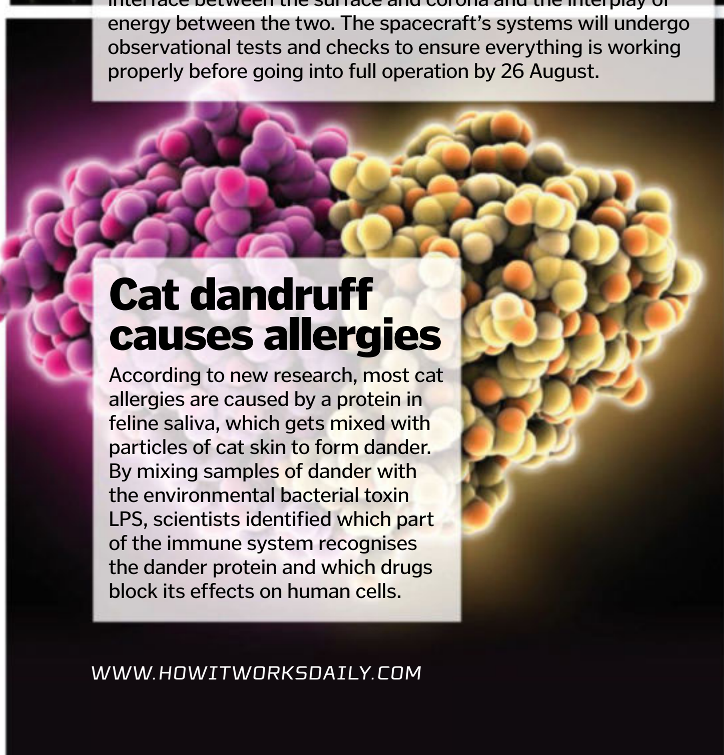
The Yellow Sea has turned green

A suffocating yet non-poisonous green algae called Enteromorpha prolifera washed up on the shoreline of Qingdao beach in eastern China in July. While this type of seaweed is found all over the world, this is China's largest-ever algal bloom. Some 20,000 tons of the stuff has already been cleared from the 28,900 square kilometres (11,158 square miles) of beaches in the area.

Industrial pollution is thought to be responsible for the deluge that could severely damage local ecosystems. While the seaweed is not harmful itself the thick green blanket now covering the surface of the ocean prevents sunlight from penetrating the sea beneath, starving the water of oxygen and choking marine life.

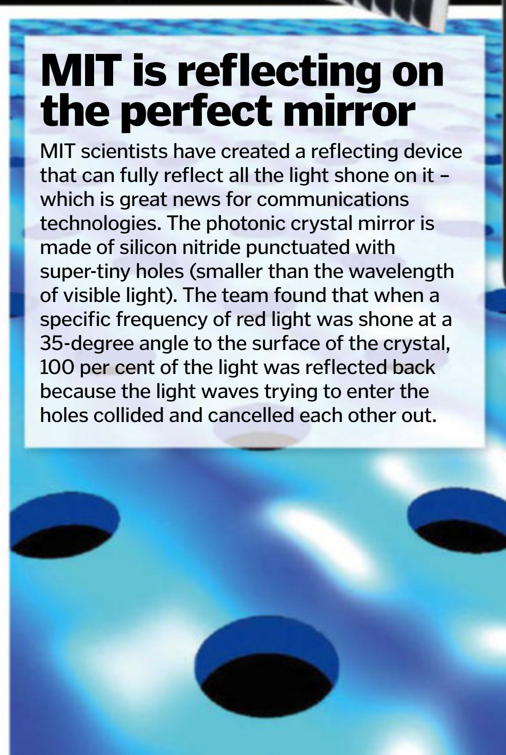
IRIS has opened its door

NASA's Interface Region Imaging Spectrograph (IRIS) opened the door to its UV telescope for the first time since the observatory launched in June this year. The telescope door is the white circular region on the left. The telescope will be trained on a small section of the Sun's chromosphere to examine the interface between the surface and corona and the interplay of energy between the two. The spacecraft's systems will undergo observational tests and checks to ensure everything is working properly before going into full operation by 26 August.



Cat dandruff causes allergies

According to new research, most cat allergies are caused by a protein in feline saliva, which gets mixed with particles of cat skin to form dander. By mixing samples of dander with the environmental bacterial toxin LPS, scientists identified which part of the immune system recognises the dander protein and which drugs block its effects on human cells.



MIT is reflecting on the perfect mirror

MIT scientists have created a reflecting device that can fully reflect all the light shone on it – which is great news for communications technologies. The photonic crystal mirror is made of silicon nitride punctuated with super-tiny holes (smaller than the wavelength of visible light). The team found that when a specific frequency of red light was shone at a 35-degree angle to the surface of the crystal, 100 per cent of the light was reflected back because the light waves trying to enter the holes collided and cancelled each other out.

The Nexus 7 is the highest-res tablet

Google's Nexus 7 from Asus has a higher-resolution display than any other tablet today – even the iPad mini. With a 1,980 x 1,200 display and 323 pixels per inch this device can boast twice as many pixels per inch as Apple's smaller iPad sibling. With better resolution and more power generally, this tablet could be the one to really dethrone the iPad dynasty.

© Bo Zhen; Getty; SPL; NASA; ESA

GREATEST INVENTIONS

From the wheel to the 3D printer, we pick 50 of history's most significant innovations that have shaped the modern world

What is it to be human? That question is hard to answer, but one thing that most would agree plays a large part in it is our creativity. Machines – even revolutionary ones – lack the ability to think outside the box, or to add two and two together and make five. They can often outperform us in many tasks – both physically and mentally – however the creative element that led to their own existence remains elusive.

And so it has been throughout time. Human ingenuity has led to the creation of thousands upon thousands of tools, machines, systems, processes and materials that have made our lives easier and helped us better understand the world. From the wheel to the refrigerator, printing press to magnetic compass, humanity has always pushed its creativity to the limit, building devices that – while sometimes seeming insignificant – have gone on to change the world in amazing ways. Of course, not every creative spark has led to the electric light bulb or microscope, but we can nevertheless always learn from our mistakes – sometimes even more than our successes.

Here are just 50 of the millions of inventions that have been produced due to our insatiable hunger to make our lives that little bit easier. You never know, perhaps they'll inspire you to think up some innovations of your own…

1. Basic tools

2.6 million years ago

Early humans discovered the use of sharp stones early on in the Palaeolithic period and, after identifying their ability to cut and skewer, began artificially sharpening stones of their own accord and fashioning them into primitive weapons. This tool-making evolution enabled us to perform a wide array of tasks that before would have been impossible – or at least much more difficult – such as hunting, skinning animals and cutting wood. The earliest stone tools discovered to date are from 2.6 million years ago; they were unearthed in Ethiopia.

4. Maps

6500 BCE

From a modern perspective it's hard to imagine a time when maps didn't exist, however for thousands of years that was the case, with humans living without them up to around 6500 BCE when the art of cartography emerged in Ancient Babylonia. One of the earliest examples is a wall map found in Çatalhöyük (now in Turkey), clearly showing the layout of the town and the surrounding landscape.

6. Glass

4500 BCE

Just think, where would we be without glass? Living in much colder or darker homes, that's for sure. Indeed, since its invention some 4,500 years ago in the Bronze Age Middle East, the use of glass became more and more widespread. By the time of the Ancient Romans, glass was no longer a luxury commodity, used by many for bottles and jewellery. Today, this world-changing material features in virtually every building and vehicle on Earth.

7. Glue

4000 BCE

While these days we have artificial man-made adhesives, simpler natural glues have been used for thousands of years. Ancient Egyptian carvings that are over 3,000 years old demonstrate the use of glue to stick veneer to sycamore, while many burial sites throughout Europe have 6,000-year-old pottery that has been repaired with plant sap and bark tar. The Ancient Romans even used beeswax glues to fill in the seams of their ships.

2.6 MYA

2. Basic agriculture

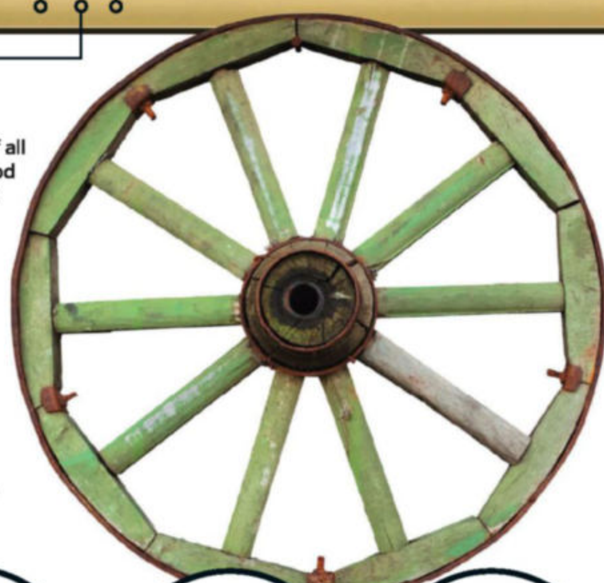
12,000 years ago

The invention of basic farming tools and techniques was vital to the development of civilisation, allowing us to transition from small hunter-gatherer groups into larger, more advanced trading societies. Evidence suggests that around 12,000 years ago planned cultivation was in effect, with specialised tools such as harvesting sickles, while advanced agricultural techniques like irrigation followed later in Mesopotamia circa 6000 BCE.

5. Wheel

5150 BCE

One of the greatest inventions of all time, the wheel has not only stood the test of time – with the oldest discovered carbon dated to around 7,150 years ago – but transformed every society or industry it has touched. From farming fields 1,000 years ago through to commuting miles into a 21st-century metropolis, the invention of the wheel has made all our day-to-day lives easier and more efficient. While rough estimates can be placed on the wheel's date of invention, who invented it is well and truly lost to the ages.



EVOLUTION OF...

3. Boat

7500 BCE

With 70 per cent of Earth's surface covered in water, there was always a demand for water-going transport – something that was first met in the mid-eighth millennium BCE. The earliest boats were dugouts: simple tree trunks hollowed out to form canoe-like vessels. But over the following centuries and millennia, they grew in size and complexity dramatically. Here we pull out some of the boat's evolutionary stages up to the present day...

Canoe
The inevitable evolution of the dugout, the canoe was fashioned around the world by peoples from the Americas, Europe and Oceania.

Chinese junk
Developed in the Han Dynasty (206 BCE – 220 CE), this was a wooden, ocean-going transport and cargo vessel with fully battened sails.

Galleon
A multi-decked sailing ship used for transport, trade and combat, the 16th-century galleon became famous for its speed and versatility.

Paddle steamer
Combining paddle-wheel propulsion and a steam engine, this became the most popular way to cross oceans in the late-19th century.

“The Ancient Romans used beeswax glues to fill the seams of their ships”

9. Weaving

3500 BCE

Weaving may not sound like a groundbreaking invention, but when the Ancient Egyptians mastered it back in the fourth millennium BCE, it revolutionised the way we dressed. This early weaving was undertaken on primitive, two-person looms that could only weave a fixed length of cloth. However, by the close of classical antiquity, dexterous horizontal and vertical weaving looms could be found throughout Asia, Africa and Europe (including Ancient Greece, as illustrated). Today, weaving is undertaken on a massive scale by large, shuttleless machines such as rapier and air-jet looms.

KEY PLAYERS

Leonardo da Vinci

1452-1519

This legendary Italian polymath is one of the greatest-ever inventors due to the massive catalogue of inventions he created in his lifetime. The extensive list includes many objects that are still in use today, such as hydraulic pumps, mortar shells, hang-gliders and machine guns.

2500 BCE

8. Alphabets

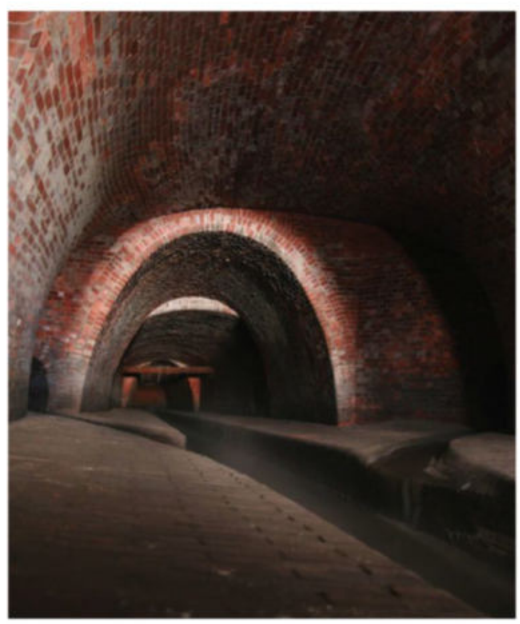
4000 BCE

The phonetic alphabet is believed to have been devised around 6,000 years ago by the Canaanite peoples of the Middle East as a simplified version of Egyptian hieroglyphs. This language, which incorporated a mixture of the earlier hieroglyphic system and later Semitic letters, enabled the average person to write down their thoughts and feelings for the first time. Previous to this, the physical writing of information had been a highly restricted practice, typically the reserve of priests and the well educated. Today, all subsequent alphabets have descended in one way or another from this first phonetic system and are used to communicate the world over.

11. Sewage system

2500 BCE

The creation of the first sewerage system surely has to be one of the most fundamental life-bettering inventions of all time. Starting as simple, below-floor-level cesspits before evolving into brick-lined drains and, in more recent times, full-blown underground networks of tunnels and recycling centres, sewage systems have been an intrinsic part of civilisation since circa 2500 BCE. Excavated homes from the Indus Valley in Pakistan are some of the earliest to reveal the remains of connections to a large sewage drain.



Cruise ship

With the largest cruise ships capable of carrying over 5,400 passengers, today's vessels tend to resemble floating cities more than boats.

10. Soap

2800 BCE

Soap, in its most fundamental form, first emerged in Babylonia almost 5,000 years ago. This crude soap was a mixture of fat and ashes, which were boiled together in a big cauldron and then stored in clay pots. This emulsifying agent was later refined in Spain during the 19th century into the hard white soaps we are more familiar with today. Originally this new take on soap was made from olive oil and the ashes of the salsola plant.

12. Magnetic compass

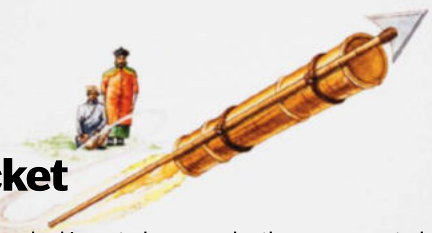
200 BCE

It was the Ancient Chinese who first discovered the orientating effect of rare ore magnetite and, following this, they put it to use as a crude form of compass in the lodestone. It was more than 1,000 years later before a true navigational compass appeared – again devised in China. The compass was a remarkable milestone in navigation, removing the need for sailors to rely on landmarks and celestial bodies to plot a course and thereby mitigating the uncontrollable factors of overcast weather and darkness. The compass undoubtedly played a huge part in the Golden Age of Exploration during the 16th and 17th centuries.

13. Parchment

150 BCE

While papyrus scrolls and cuneiform tablets predated parchment, its creation was arguably far more important in the grand history of writing, as it paved the way to the development of the first book. Papyrus only came in scroll form and was relatively stiff, while parchment – being made from the scraped skins of animals – was smooth, flexible and more resistant to variable environments and atmospheres. This allowed multiple sheets of parchment to be sewn together into larger manuscripts.



17. Rocket

904

After the Chinese had invented gunpowder they soon created something called 'fire arrows'. These weapons were standard arrows with a tub of gunpowder strapped to the shaft that exploded on contact. By the early-13th century, fire arrows had evolved into rockets, with individual arrows carried at great speed by attached rocket tubes, very much like modern-day fireworks.

18. Spectacles

1286

Today there are many people around the world with some sort of eye deficiency, so it's a good job we have eyeglasses to help correct vision. This wasn't the case before the late-13th century, as prior to the invention of the spectacles in Italy the optical powers of lenses were poorly understood. Even after they were developed, only the richest visually impaired would have been able to afford a pair of specs to help them see.

19. Clocks

Late-13th century

While water clocks and, even earlier, sundials had been in use for centuries, it wasn't until the end of the 13th century that weight-powered mechanical clocks began to appear. Who exactly invented the first mechanical clock is lost in time – excuse the pun – but records show that complex escapements and mechanical clocks were becoming commonplace in church towers by the close of the 14th century in Europe. Since then, the accuracy of mechanical clocks has been consistently improved, doubling in accuracy about every 30 or so years on average.

200 BCE

14. Calendar

46 BCE

While the Sumerian lunar calendar had been in use since about 2000 BCE, the invention of the Julian calendar – a reform of the earlier Roman calendar – by Julius Caesar in 46 BCE proved to be one of the most resilient and well used of all time. Indeed, it wasn't until 1582 that it was superseded by the Gregorian calendar, which was introduced by Pope Gregory XIII. Today, the Gregorian calendar is internationally the most widely used calendar.

15. Gunpowder

800

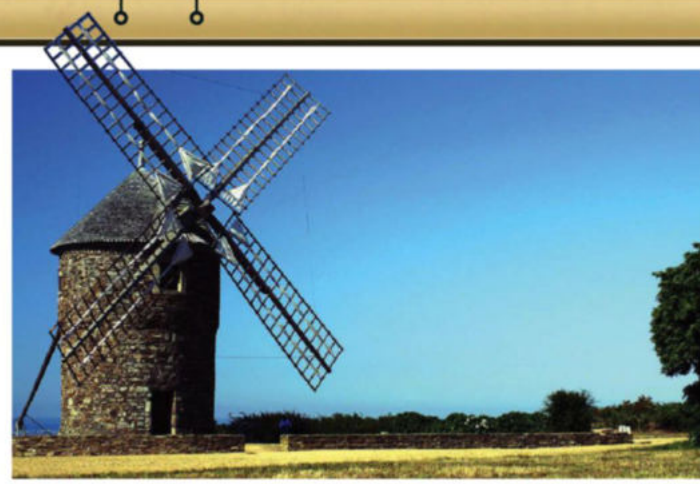
Invented by Chinese alchemists, gunpowder is one of the deadliest-ever human creations. In its original form – a mix of potassium nitrate, charcoal and sulphur – it was used to power a fire lance, a primitive spear launcher made from a bamboo tube and reinforced with metal hoops. Through the Middle Ages its use became ever-more refined for shooting cannons and muskets.

"Gunpowder was [first] used to power a fire lance, a primitive spear launcher"

16. Windmill

800

The windmill was invented in eastern Persia during the ninth century. According to surviving documents, these early windmills had between six and 12 sails made up from reed and cloth matting and were used to either grind grain or draw up water – the latter typically as part of an irrigation system. The now-traditional horizontal-axle windmill (pictured) – such as those found in Holland – was invented much later, appearing in Europe during the 18th century. Today, windmills have declined in use, though their principles still apply to newer inventions such as wind turbines.



EVOLUTION OF…

23. Telescope

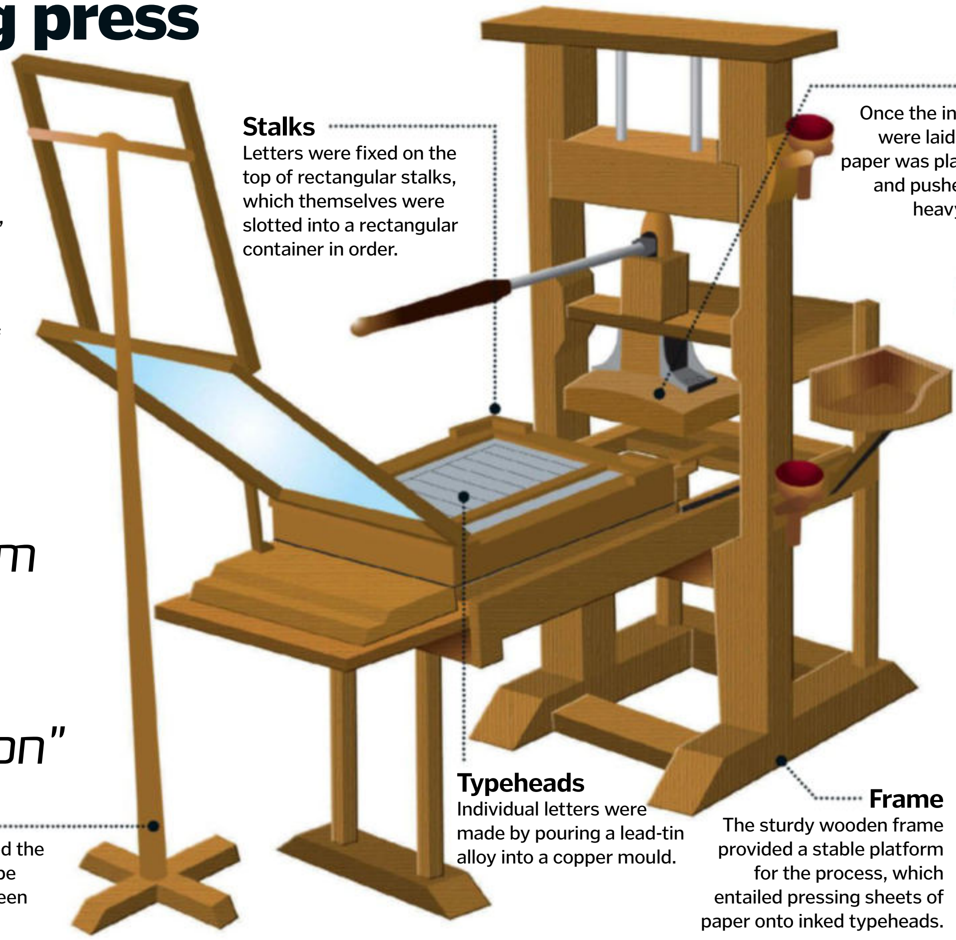
1609

The invention of the telescope is generally now attributed to the German-Dutch lensmaker Hans Lippershey, but many have argued it was not until Galileo Galilei copied his designs and improved upon them in 1609 that the telescope, as we know it today, was born. Galileo's telescope reportedly offered 20x magnification and through it the astronomer discovered four of Jupiter's satellites and that the Sun was covered in spots. Since then, the telescope has evolved massively and today enables us to explore some of the very deepest reaches of space. Check out some of the key points in the telescope's development now…

20. Printing press

1450
Surely this is one of humankind's most edifying inventions. The printing press – built by Johannes Gutenberg in the mid-15th century – allowed documents and books to be produced quickly and cheaply in bulk, bringing literature to the masses. Indeed, this device wrenched the knowledge of the ages away from a minority of wealthy and learned scholars and placed it in the hands of the everyday person, inspiring many to go on and make world-changing inventions of their own.

"This device wrenched knowledge from a minority and placed it in the hands of the everyday person"



Stalks
Letters were fixed on the top of rectangular stalks, which themselves were slotted into a rectangular container in order.

Press
Once the inked typeheads were laid out, a sheet of paper was placed over them and pushed down with a heavy screw clamp.

Holder
A holding device secured the paper over the inked type by sandwiching it between two wooden frames.

Typeheads
Individual letters were made by pouring a lead-tin alloy into a copper mould.

Frame
The sturdy wooden frame provided a stable platform for the process, which entailed pressing sheets of paper onto inked typeheads.

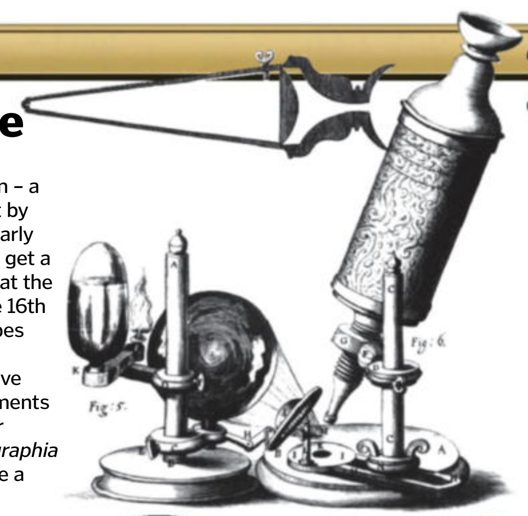
KEY PLAYERS

Archimedes of Syracuse
287-212 BCE
Not only was Ancient Greek polymath Archimedes (of 'Eureka!' moment fame) one of the greatest mathematicians of all time, but he was also one of the greatest inventors. A few of his best-known accomplishments include the Archimedes screw, the claw of Archimedes and the odometer. Archimedes was killed before his time during the Siege of Syracuse.

1609

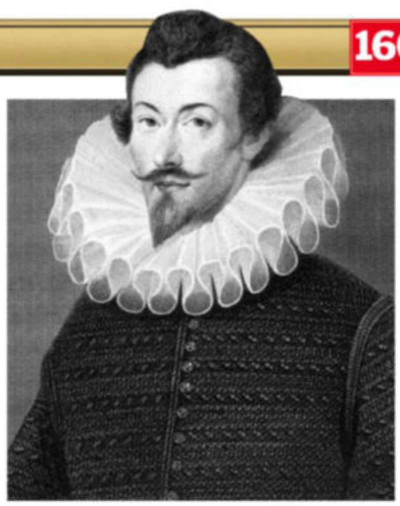
21. Microscope

1590
It wasn't until Zacharias Janssen – a Dutch lensmaker – realised that by inverting the lens structure of early prototype telescopes you could get a high degree of magnification that the microscope was invented in the 16th century. These initial microscopes were simple compound types, combining a magnifying objective lens with an eye lens. Advancements soon followed though and, after Robert Hooke published *Micrographia* in 1655, the microscope became a staple tool for any scientist.



22. Flush toilet

1596
Toilets had been in use for centuries by the end of the 16th century, often with a sewage system. However, these toilets were in reality mere pits/holes, with no moving mechanisms in the waste removal process. That changed in 1596 when writer John Harington installed a flush toilet in his house in Kelston, England. The design used a special valve to let water out of a suspended tank and into the bowl, flushing away the waste.



Lippershey telescope
A simple tube filled with a convex and concave lens, the original Dutch-made telescope offered a rather basic 3x magnification. Nevertheless, it was quickly sold throughout the Netherlands and much of Europe.

Galileo telescope
One of the most important in popularising these instruments, the Galilean telescope was the first to offer large magnifications of 20x and up. After Galileo showed his telescope to the Doge of Venice it took off all over the continent.

Newtonian telescope
Dissatisfied with flaws in refracting telescopes, Isaac Newton invented the reflecting telescope in 1668, presenting a second refined version to the Royal Society in 1672. Today, the majority of domestic telescopes are of the reflecting type.

Herschel's 40-foot telescope
British astronomer William Herschel built over 400 telescopes, but his largest was a 12-metre (40-foot) focal length reflecting telescope made in 1789. On the first night of using it, he discovered a new moon of Saturn.

Very Large Telescope
One of the most advanced and powerful telescopes that exists on the planet today, the European Southern Observatory's Very Large Telescope (VLT) array, based in Chile, is capable of imaging entire galaxies in phenomenal detail.

26. Vaccinations

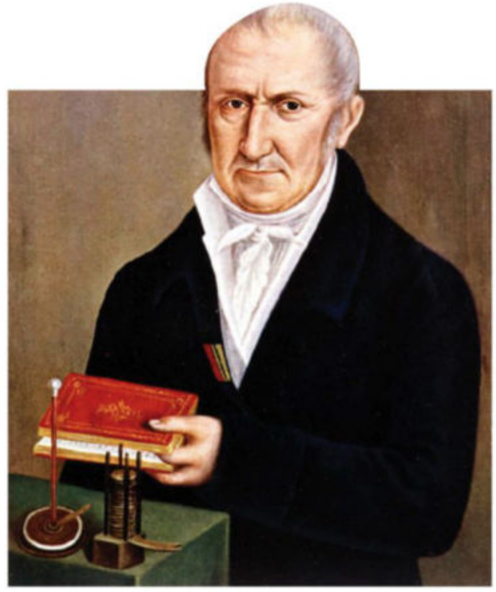
1796

Dying of smallpox was not a pleasant way to go, with a slow and painful death almost guaranteed. On the other hand, catching cowpox was only a minor inconvenience and, better yet, it prevented you from catching smallpox. English doctor Edward Jenner noticed this link and, after experimenting on some of the local dairy workers, published his results in 1798. He invented a vaccine that later became mandatory, though there were a lot of naysayers before his research was recognised.

27. Battery

1799

When Italian scientist Alessandro Volta made his voltaic pile in 1799 he started the journey to today's widespread electrochemical batteries. The pile, which was a stack of silver and zinc discs separated by pieces of brine-soaked fabric, was crude but when its ends were connected via metal wire, it produced a small electric current. In the years following the pile's invention, the battery was improved again and again, and now it is a fundamental source of portable power many of us couldn't live without.



EVOLUTION OF...

24. Engine

1712

From the 1712 Newcomen steam engine through to Karl Benz's two-stroke petrol engine used in cars and on to today's hi-tech hydrogen varieties, there is no doubt that the engine is one of the most significant inventions ever. Its usefulness has essentially been unrivalled for over 300 years as a motive force and, looking to the future, it seems to have plenty of life left in it. We pick out some of the key developments in its evolution now...

Steam engine
Steam engines date back to the first century CE, but it wasn't until Thomas Newcomen's engine in 1712 that they became useful machines.

Petrol engine
Karl Benz's invention of a reliable two-stroke petrol engine marked the end of the steam engine and led to the proliferation of the motor car.

Diesel engine
While the petrol engine was more momentous, Rudolf Diesel's creation of the diesel equivalent was just as useful and more eco-friendly too.

Electric engine
When Camille Jenatzy built an electric car in 1899, his electric engine was openly mocked. The car went on to break the land speed record.

25. Electricity

1752

Okay, so this isn't an invention but rather a discovery. It is still, however, so momentous that it deserves a mention. While scientists had been fascinated with lightning and electricity for thousands of years – indeed, great philosopher Thales of Miletus undertook numerous experiments into the nature of static electricity in 600 BCE – it wasn't until Benjamin Franklin studied the phenomenon in 1752 that the two were reconciled and its true power realised. Following Franklin's work, electricity was harnessed in increasingly diverse ways, with Michael Faraday using it to lay down the foundations for the electric motor.

KEY PLAYERS

Thomas Edison

1847-1931

Probably the greatest American inventor ever, Edison was responsible for the first commercially successful light bulb, the phonograph, the electric vote recorder, the railway turntable and the kinetographic camera (one of the first motion-picture cameras), to name a few.

28. Canned food

1810

While canned food may get a bad rap today for not being 'fresh', it has been and remains a critical source of nourishment in many parts of the world. Indeed, canned food has many benefits, including acting as a preservative and providing a protective container for transportation. As such, when it was invented in the early-19th century, it radically transformed what the average person ate.

29. Photography

1826

For centuries the only way to record a person or place was with paint, which was a time-consuming and expensive process. That all began to change in 1826 when Joseph Nicéphore Niépce – a French inventor from Chalon-sur-Saône – produced the first permanent photographic image by covering a pewter plate with bitumen. Niépce continued to experiment and, after replacing the bitumen with silver, produced one of today's earliest surviving photographs.

30. Light bulb

1835

Many years before Thomas Edison and Joseph Swan introduced their own light bulbs to the world, a Scotsman called James Bowman Lindsay demonstrated a constant electric light at a public meeting in Dundee. Reportedly, Lindsay's light was so powerful and stable – for 1835 at least – that he could read his book from a distance of 0.4 metres (1.5 feet). Lindsay had invented the world's first electric light bulb, however he neither patented the device nor sold it, instead moving on to wireless telegraphy. Regardless, Lindsay's innovation was continuously honed in the following decades and, after Edison married a stable electric generator to this revolutionary light-giving device, the stage was set for its widespread adoption. Today, it's hard to imagine a world without electric light bulbs and they're often voted one of the greatest inventions of all time in polls.

Hydrogen engine
Still in development today, the hydrogen engine could potentially render petrol-based engines obsolete, helping to cut levels of pollution.

31. Plastic

1856

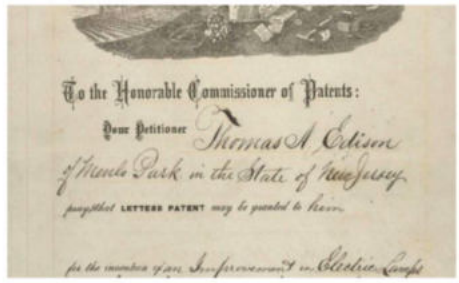
In 1856 British scientist Alexander Parkes created the first man-made plastic from cellulose treated with nitric acid. Trademarked as Parkesine, Parkes' invention soon won him a bronze medal at the 1862 Industrial Exhibition in London and, as a result, he decided to ramp up production of the new material. Unfortunately, after beginning mass production of the plastic, a mixture of demand and high costs saw his company fail and, by 1868, Parkesine was no longer made.

Patent pending

While today the patent is best known for the ongoing corporate patent wars between companies like Apple and Samsung, originally the patent was an incredibly simple thing. When someone made an invention, their labour was protected from theft so they could enjoy any material benefits that derived from it.

The first reference of a patent system dates from 500 BCE, where in the Ancient Greek city of Sybaris 'encouragement was held out to all who should discover any new refinement in luxury, the profits arising from which were secured to the inventor by patent for the space of a year.' The history of modern patent law, however, is now widely agreed to have started in Italy in 1474, when a Venetian statute decreed that all completed inventions had to be made public to obtain any ownership rights.

From this point on patent systems evolved throughout the world, allowing civilians to freely create new inventions and advance society. Today, anyone can request a patent for an invention provided it is original and does not infringe on any previously filed patents.


To the Honorable Commissioner of Patents:
Your Petitioner Thomas A Edison
of Menlo Park in the State of New Jersey
pray that LETTERS PATENT may be granted to him
for the invention of an Improvement in Electric Lamps

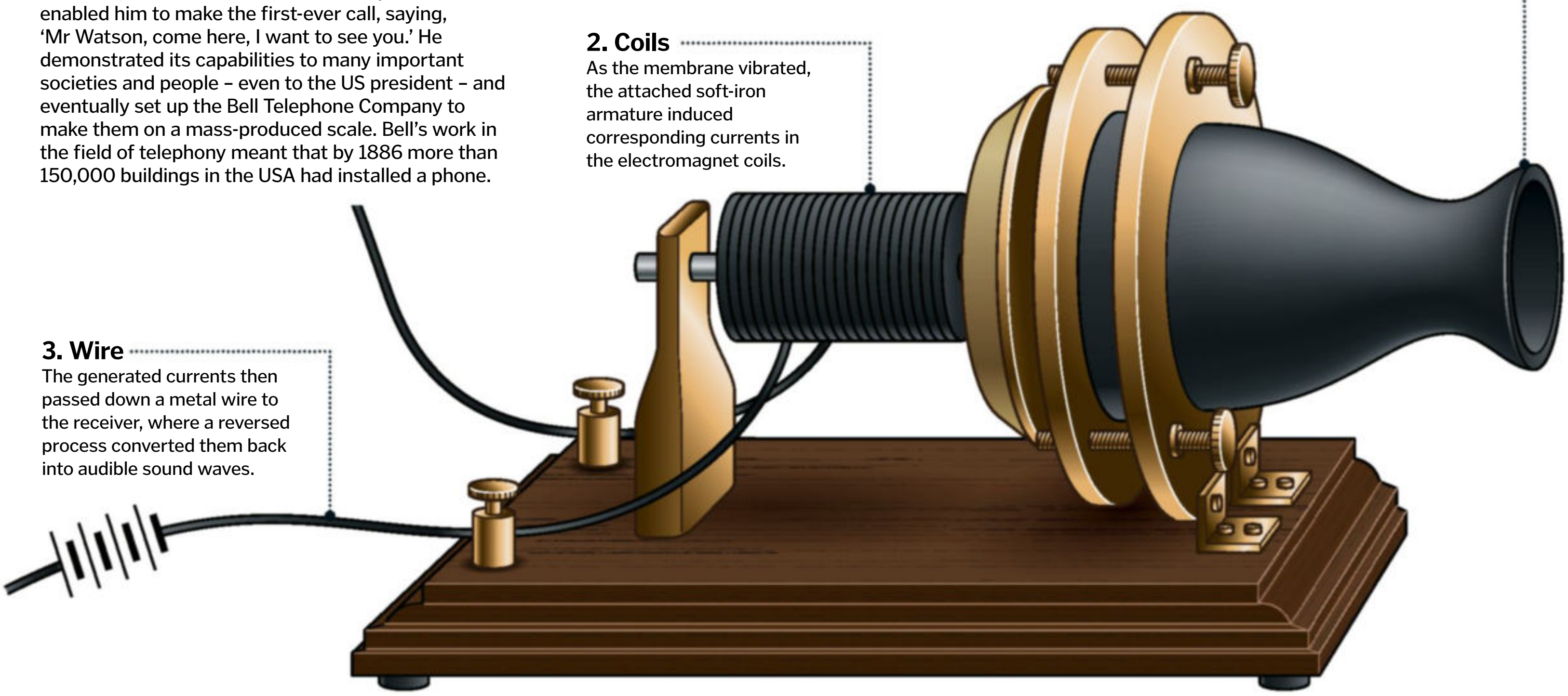
1876

32. Telephone

1876

While not the inventor of the world's first telephone (largely attributed to Antonio Meucci in 1849), Alexander Graham Bell achieved so much in its overall development – including taking out a patent for his own device in 1876 – that he is generally now credited as its inventor. Indeed, along with his assistant, Thomas Watson, Bell built a phone that enabled him to make the first-ever call, saying, 'Mr Watson, come here, I want to see you.' He demonstrated its capabilities to many important societies and people – even to the US president – and eventually set up the Bell Telephone Company to make them on a mass-produced scale. Bell's work in the field of telephony meant that by 1886 more than 150,000 buildings in the USA had installed a phone.

> "Bell built a phone that enabled him to make the first-ever call, saying, 'Mr Watson, come here, I want to see you'"



33. Phonograph

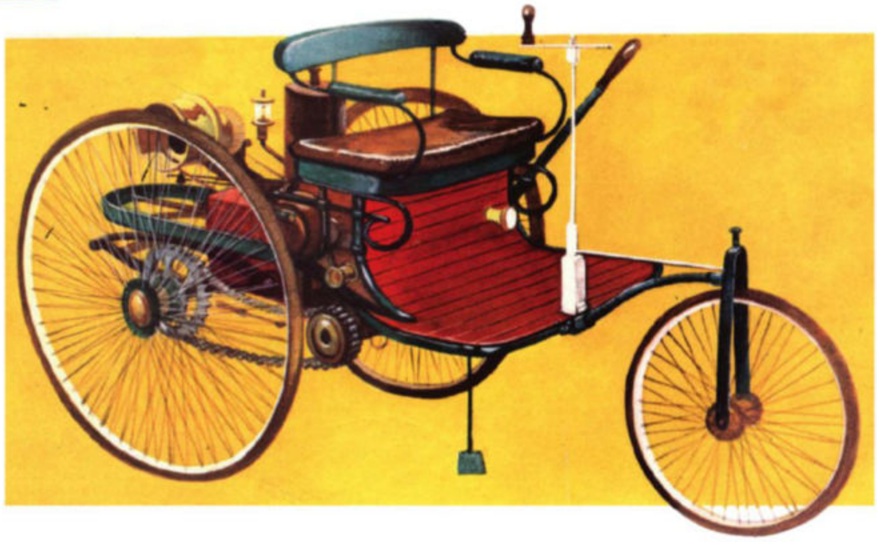
1877

The first device to be capable of recording and replaying sound, Thomas Edison's 1877 phonograph laid down the foundations for today's music industry, being quickly followed by the gramophone and, later, the turntable. Prior to this no audible moments could ever be captured or replayed. Today, radios and MP3 players allow us to listen to our favourite tunes all day long.

34. Car

1882

Taking over from steam- and horse-powered travel at the end of the Industrial Revolution, where would we be today without the car? First made in its current form in 1886 by German engineer Karl Benz, there are now more than 1 billion worldwide, and that number is set to keep growing. Newer designs are looking to solve the problem of pollution by using alternative energy sources, such as hydrogen.



EVOLUTION OF...

36. Wireless communications

1891

Responsible for eventually giving us the television, mobile phone, radio, radar, satellite navigation and even wireless internet access, Nikola Tesla's work in 1891 creating a wireless communications network was surely one of the most inventive spells of his career. Since Tesla's network, wireless communications have gone from strength to strength, as the following devices show...

Radio
Sir Oliver Lodge sent the first transmission signal in 1894 – a year before Marconi, who was later awarded the wireless telegraph patent.

Television
Scottish inventor John Logie Baird demonstrates the world's first moving image on his 'televisor' device – a mechanical precursor to the TV.

Mobile phone
The first handheld mobile phone is demonstrated by two employees at Motorola. It weighs in at a rather hefty one kilogram (2.2 pounds).

Wi-Fi
While wireless internet existed in academic facilities, it wasn't until 1997 that standards were laid down for its widespread adoption.

1877

35. Skyscraper

1884

The invention of steel-girder skyscrapers enabled architects to move away from the constraints of load-bearing walls and towards steel-framed structures that granted more freedom and creativity. The first of these buildings was architect William Le Baron Jenney's ten-storey Home Insurance Company Building, completed in 1885. As soon as it was built – and proven a success – the technology proliferated rapidly and soon rival architects tried to outdo each other, designing ever taller and more complex buildings.

KEY PLAYERS

Benjamin Franklin

1706-1790

Famed for his experiments with electricity, Franklin was also quite an inventor, designing the Franklin stove, bifocal glasses, a flexible urinary catheter, the lightning rod and the glass armonica. He was considered one of the most important figures in the American Enlightenment.

EVOLUTION OF...

39. Television

1926

Whether or not you think we watch too much TV these days, it's hard to argue that it has not had a beneficial effect since 1926. From allowing national leaders to address the public in times of emergency to educating and entertaining the masses, John Logie Baird's invention has done much good over the last 87 years. Check out some of the telly's milestones now...

Accidents of invention

Penicillin
When Scottish scientist Alexander Fleming decided to take a month-long holiday in August 1928 to see his family, he left his London lab in a bit of a mess – including abandoning numerous Petri dishes of staphylococci. Upon his return he noticed that on one of the dishes a mould had grown that had killed any nearby staphylococci. After regrowing the mould in a pure culture he found that it destroyed a number of disease-causing bacteria. As a result, penicillin – one of the most successful antibiotics to this day – was born.

Vulcanised rubber
19th-century rubber king Charles Goodyear spent years trying to make a rubber that was easy to manufacture yet resistant to heat and cold. After many failed attempts one day he just happened to drop a rubber mixture on a hot stove. Believing it ruined, Goodyear retrieved the charred rubber and, when holding it, discovered it was hardened but still flexible. After a little experimentation, he quickly realised that by heating a mixture of rubber and sulphur he could create his desired vulcanised rubber – today used in tyres, shoes and more.

Coca-Cola
Probably the most commercially successful accident of all time, the soft drink Coca-Cola was not the corporate juggernaut it is today when invented but rather a medicinal cure for headaches… Or so the pharmacist John Pemberton from Atlanta, GA, believed when he began selling his secret mixture in 1886 for five cents a pop. 50 years later and Coca-Cola had become a national symbol of America due to its phenomenal success; in fact, in 2011 it was voted the most well-known brand in the world.

Microwave oven
Percy LeBaron Spencer was not even trying to invent anything when he accidentally conceived of the microwave oven. Working at Raytheon Company during the 1940s, by chance, Spencer noticed one day while walking past a radar tube that a chocolate bar that was in his pocket had melted. After testing the effects with other foods – including popcorn – Spencer realised that magnetrons could be used to cook food, thus devising the concept of the microwave oven.

38. Refrigerator

1922
One of the most useful day-to-day inventions of the 20th century, the refrigerator allows our food to be stored over long periods, reducing the growth of bacteria dramatically. It was invented originally in 1922 when two students at the Royal Institute of Technology in Stockholm, Sweden, created a gas-absorption chilling cabinet. Unlike modern fridges though this device did not use an electrically driven compressor to maintain internal temperature, but instead an ingenious system of state-changing gases. After realising its potential the inventors put the refrigerator on sale. Unfortunately, it never really caught on, leaving the later electric fridge to make the jump to mass-market success.

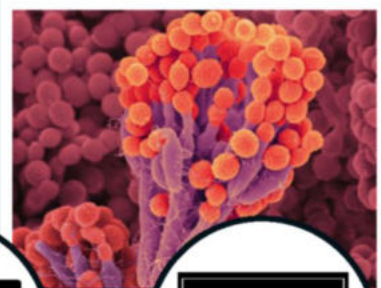
1928

37. Aeroplane

1903
The Wright Brothers' Wright Flyer in 1903 kick-started the age of aviation, with rotor and then jet-powered craft transforming travel in the 20th century. From military fighter jets through to supersized passenger aircraft, air travel means we can reach each other much faster than ever before. To think that within just 73 years we went from the primitive Wright Flyer, which only travelled a distance of 260 metres (852 feet) to the Aérospatiale-BAC Concorde supersonic passenger jet, capable of cruising comfortably at 2,172 kilometres (1,350 miles) per hour for thousands of miles is simply mind-blowing.

40. Penicillin

1928
Discovering penicillin might have been a happy accident, but nevertheless Alexander Fleming's find was a pivotal moment in modern medicine, with the bacteria-fighting antibiotic quickly rolled out. Fleming would go on to win a Nobel prize in 1945 for his work. Today, penicillin is available commercially for treating a wide range of infections.



Farnsworth
American inventor Philo Farnsworth makes the first all-electronic TV that is commercially viable, receiving a patent for his device in 1930.

Mass-market
RCA starts the era of mass-produced TVs with the release of the RCA 630TS in 1946. By 1950 the number of TVs has climbed to the millions.

Westinghouse colour
Introducing colour, the Westinghouse H840CK15 goes on sale for $1,295. With only 500 built, it will be 15 years before colour TV goes mainstream.

Casio TV-10
The first LCD TV to be sold commercially is the TV-10, which while only offering standard low resolutions kick-starts the flat-panel TV market.

LED backlight
The first LED TV – a flat-panel screen that uses LEDs to illuminate the LCD panel instead of cathode lighting tubes – is produced by Sony.

46. Space probe

1959

Luna 1 (pictured left) wasn't the first space probe to be built, but it was the first to successfully leave a geocentric orbit – the key criterion for classifying one today. The probe was built as part of the USSR's Luna programme in 1959 and paved the way for a series of other Luna probes that would explore the Moon in unprecedented detail. Today, we have created space probes that are so advanced they can image alien worlds in high definition and travel to the farthest reaches of our Solar System and beyond.

EVOLUTION OF...

49. Personal computer

1973

Be it a desktop, laptop, tablet or smartphone, the average person owns at least one personal computational device, for performing a variety of tasks. Whether it's for writing letters, receiving mail, checking the weather, making phone calls, shopping, playing games, calculating sums or booking a holiday, computers can handle it – and a whole lot more. Indeed, the empowering qualities of the PC are massive and it is easy to see why many argue it's the most important device on Earth.

1935

41. Radar

1935

It's funny to think that the radar, one of today's most useful inventions, was born out of a British-funded 'death ray' project during the runup to WWII. But that is exactly what the British government asked Scottish scientist Robert Watson-Watt to build: a machine to 'destroy personnel'. Watson-Watt realised the death ray was impossible to build, but did suggest that radio waves could be used to monitor distant objects.

"The death ray was impossible, but radio waves could monitor distant objects"

43. Microwave oven

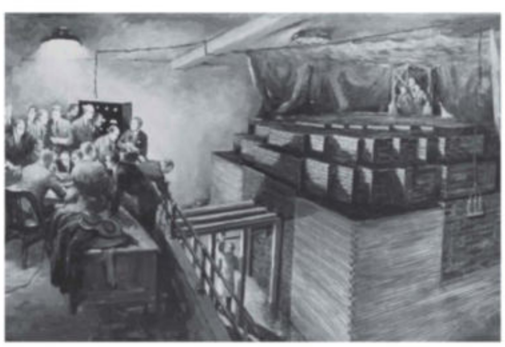
1947

The microwave oven was created by chance (see 'Accidents of invention'), but despite its serendipitous origins, the first commercial microwave was sold in 1947, with the Raytheon Company releasing its Radarange unit. The Radarange was 1.8 metres (six feet) tall, weighed 340 kilograms (750 pounds) and cost $5,000 – over £33,800 ($51,000) by modern standards! Today, the microwave is a staple feature in most kitchens as a speedy means to cook our food.

42. Nuclear reactor

1942

The world's first nuclear reactor was the Chicago Pile-1 (pictured), which was constructed as part of the USA's Manhattan Project in WWII. Built under the western stands of Stagg Field at the University of Chicago, the reactor was fairly crude, comprising a pile of uranium pellets and graphite blocks. Regardless of its rustic build, the reactor initiated the first self-sustaining nuclear chain reaction on 2 December 1942 and kick-started the age of nuclear power.



45. Credit card

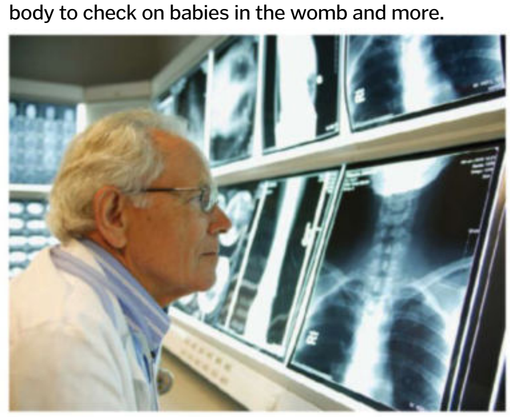
1958

Almost nobody goes anywhere today without some form of debit or credit card, but not so long ago all we had was physical currency. However in 1958 the Bank of America launched its BankAmericard credit card in Fresno, CA. Despite the credit card system being abused by fraudsters in its first year, the BankAmericard was eventually a success and, in 1976, changed its name to Visa. Today, Visa cards are one of the most widely used payment cards on the planet.

44. Medical imaging

1953

Medical imaging techniques such as ultrasonography – invented in 1953 at the University Hospital in Lund, Sweden – have revolutionised the field of medicine, granting doctors an unprecedented window into their patients' bodies. Today, ultrasound scans use probes with acoustic transducers to transmit pulses into the body to check on babies in the womb and more.



47. Internet

1960s

Another invention to which no firm date nor name can be ascribed, the internet nonetheless remains an absolute necessity for a top inventions list. With origins buried in US military facilities during the Sixties as a way to deliver fault-tolerant communication between individual computer networks, the internet soon grew in scale, with the development of increasingly large and complex networks. By the early-Eighties an identifiable backbone of the internet had emerged with its potential being realised, both commercially and academically. As a result, companies and institutions started linking their own networks and – along with the birth of the World Wide Web – a new era of online communication, business and entertainment had dawned.

KEY PLAYERS

Tim Berners-Lee

1955 – present

As the main brain behind the World Wide Web, Berners-Lee revolutionised communications. While the internet existed pre-1989, it was only used by a select few; the World Wide Web brought it to the masses.

48. Satellite

1962

Military and governmental satellites had existed for over half a decade when the Telstar satellite was launched into space on top of a Thor-Delta rocket on 10 July 1962. But that didn't stop it from becoming one of the most important satellites of all time. This was because the Telstar was the first commercially funded initiative to develop satellite communications over Europe – a technological advance that would lead on to today's widespread satellite-reliant communications and entertainment. Indeed, Telstar would go on to successfully transmit the world's first transatlantic television pictures, telephone calls and fax images. Telstar 1 is still in orbit around Earth but is no longer functional.

Xerox PARC
This early personal computer sets the benchmark for their design, incorporating a monitor, keyboard, mouse and graphical user interface (GUI).

Commodore PET 2001
One of the first mass-market PCs, the PET 2001 featured a 1MHz CPU and up to 96KB of memory. It came in a one-piece form-factor, unlike the PARC.

IBM PC 5150
Tech giant IBM's first mass-produced PC sold fantastically well and went on to become a business industry standard. The IBM 5150 had a 4.77MHz CPU.

Power Mac 9500
One of the first of a new wave of hi-spec PCs, the Mac 9500 helped popularise the separate desktop tower case and now-widespread PCI standard connector.

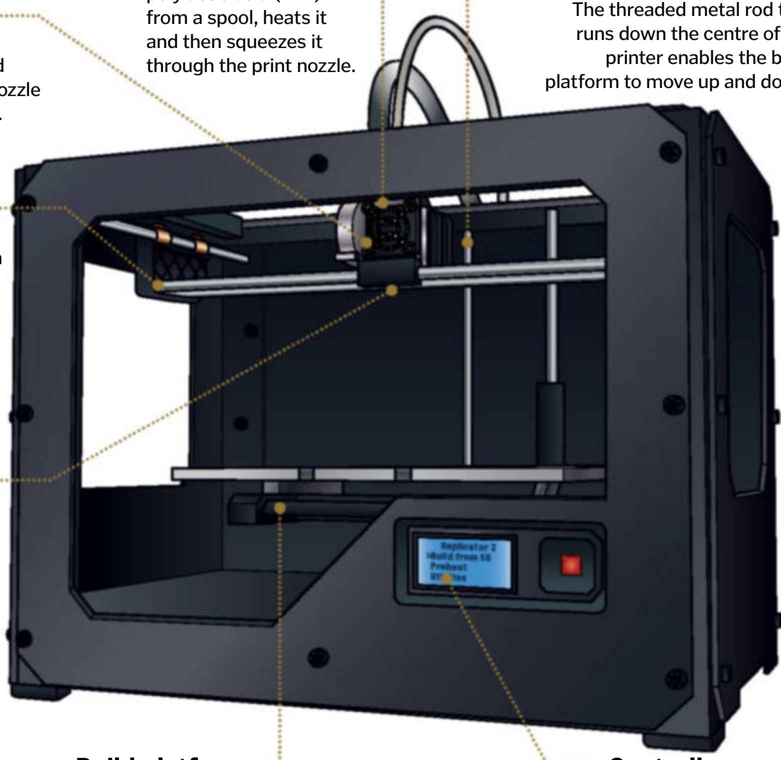
iMac
The iMac helped push the now popular all-in-one unibody design standard, with high-resolution LED screens and super-fast, multi-CPU PCs now the norm.

1984

Extruder
The extruder draws in polylactic acid (PLA) from a spool, heats it and then squeezes it through the print nozzle.

Cooling fan
An active cooling fan blows on the liquefied PLA as it leaves the nozzle so it solidifies quickly.

Z-axis rod
The threaded metal rod that runs down the centre of the printer enables the build platform to move up and down.



Gantry
The extruder is secured to a gantry in the top of the printer. The extruder runs on the gantry to allow for each layer's precise positioning.

Print nozzle
The opening on the end of the extruder from which the heated PLA filament emerges to be deposited onto the build plate.

Build platform
The support for the build plate, where the PLA is deposited. The build plate can be level adjusted to suit a range of printing projects.

Controller
Instruction sets for an object's cross-sectional layers are fed through the printer's motherboard and into the extruder controller.

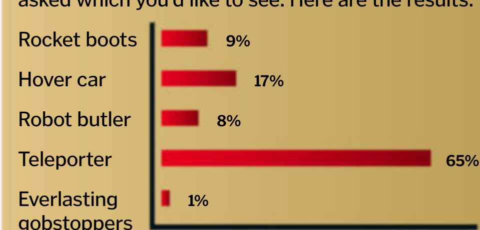
50. 3D printer

1984

And so we come to the last of our 50 inventions and, in some respects, we have come full circle, as we end with an invention that is arguably the closest thing we currently have to a machine that can create more machines! And that is the 3D printer, a device born in the mid-Eighties that – fed with CAD designs – can build objects, sculptures, gears, component parts, organs, artificial limbs, toys and much more through an ingenious layering of liquid plastics. The complexity of some of the things modern 3D printers are capable of making is truly astounding and, with work already underway to upscale both their commercial availability and their potential applications – such as a project to make a printer capable of printing entire houses – this particular invention has a very bright future ahead of it.

READERS' FANTASY POLL

For fun, we picked five fantasy inventions and asked which you'd like to see. Here are the results.



Solar storms

Every 11 years our Sun reaches a peak of activity that makes its influence felt across the Solar System, but what causes it?

Even as you read this, enormous explosions are wracking our local star, 150 million kilometres (93 million miles) from Earth. Twisted lines of magnetic field are channelling hot gas far above the surface of the Sun, occasionally 'short-circuiting' to release incredible amounts of energy that fires out particles across space at up to 80 per cent the speed of light.

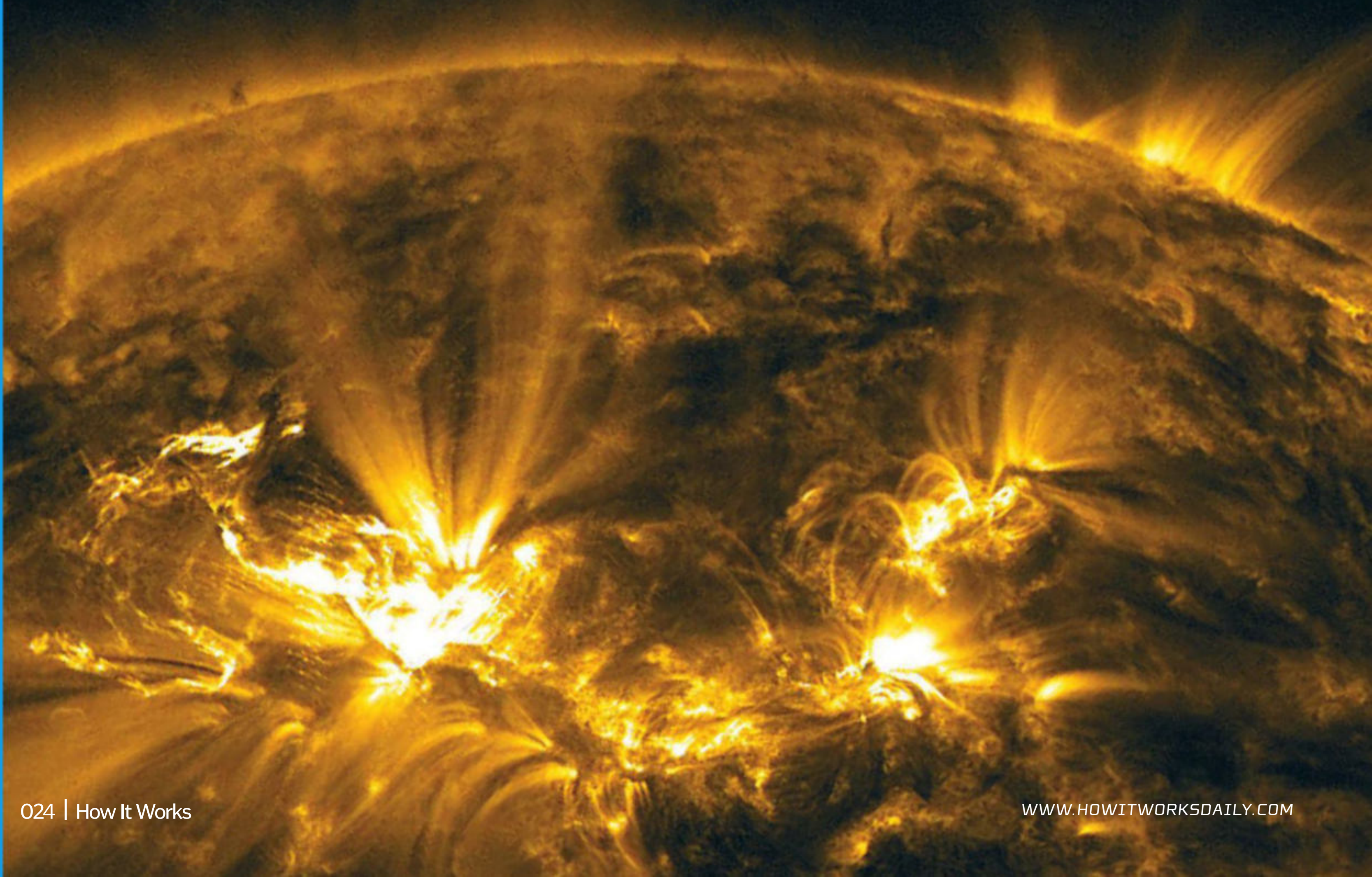
2013 marks the latest 'solar maximum', the centrepiece of an 11-year period of activity in the Sun's upper layers that is officially known as Solar Cycle 24. At its peak, the Sun's activity is expected to release epic levels of energy in bursts that will make themselves felt across the Solar System. While astronomers on Earth will watch eagerly for spectacular displays of the polar auroras (northern and southern lights), engineers will be on the alert for trouble. During the 1989 maximum, a solar storm triggered a blackout across Canada and north-east USA as it overloaded electricity grids, while a decade before, a similar event sent NASA's Skylab space station plunging back to Earth in a premature, uncontrolled descent.

Already in 2013, solar flares have briefly disrupted GPS satellite navigation signals and radio communications through their effects on the ionosphere – an upper region of our planet's atmosphere that is often used to send long-distance radio signals.

The solar maximum changes the Sun in a variety of ways. The number and size of sunspots on its visible surface is at its greatest, turning the bright orb into a mottled, blotchy disc of light when it is projected through safe viewing equipment. Seen via special filters, the disc of the Sun reveals bright loops around its edges, known as prominences, and dark streaks across its face, called filaments.

Prominences and filaments are, in fact, the same phenomenon, appearing bright against the background of space but dark against the hotter solar surface. Bright spots above the solar disc mark the locations of huge solar flares, and seen from space or during an eclipse, the Sun's outer atmosphere, or corona, is much bigger and brighter than normal.

Although for years we believed that the Sun's overall energy output changed very little throughout the cycle, in 2009 astronomers



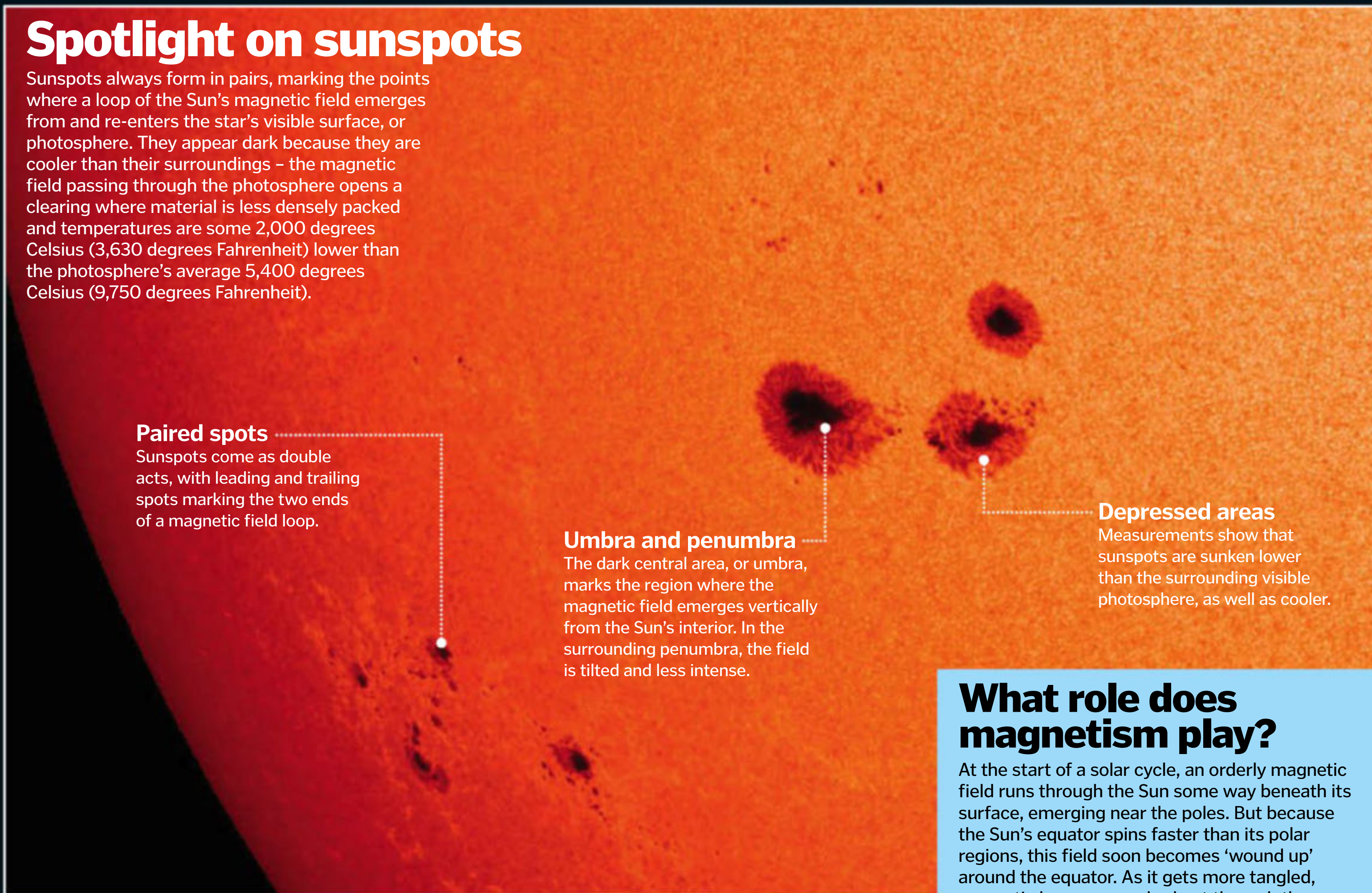
RECORD BREAKERS
FLARE POWER

1 billion

SOLAR FLARE ENERGY OUTPUT

The energy released in a solar flare is equivalent to over a billion megatons of TNT explosive – that's approximately one per cent of the Sun's total energy output per second.

DID YOU KNOW? *The 2003 'Halloween superflare' was so powerful that it overloaded the sensors attempting to measure it*



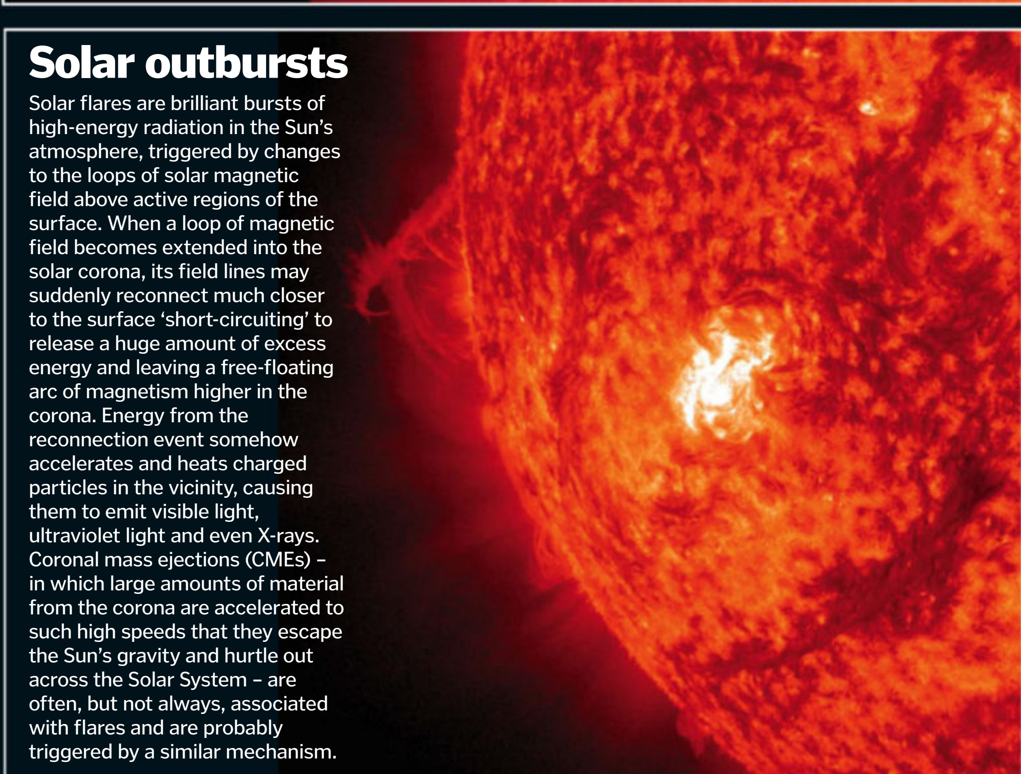
Spotlight on sunspots

Sunspots always form in pairs, marking the points where a loop of the Sun's magnetic field emerges from and re-enters the star's visible surface, or photosphere. They appear dark because they are cooler than their surroundings – the magnetic field passing through the photosphere opens a clearing where material is less densely packed and temperatures are some 2,000 degrees Celsius (3,630 degrees Fahrenheit) lower than the photosphere's average 5,400 degrees Celsius (9,750 degrees Fahrenheit).

Paired spots
Sunspots come as double acts, with leading and trailing spots marking the two ends of a magnetic field loop.

Umbra and penumbra
The dark central area, or umbra, marks the region where the magnetic field emerges vertically from the Sun's interior. In the surrounding penumbra, the field is tilted and less intense.

Depressed areas
Measurements show that sunspots are sunken lower than the surrounding visible photosphere, as well as cooler.



Solar outbursts

Solar flares are brilliant bursts of high-energy radiation in the Sun's atmosphere, triggered by changes to the loops of solar magnetic field above active regions of the surface. When a loop of magnetic field becomes extended into the solar corona, its field lines may suddenly reconnect much closer to the surface 'short-circuiting' to release a huge amount of excess energy and leaving a free-floating arc of magnetism higher in the corona. Energy from the reconnection event somehow accelerates and heats charged particles in the vicinity, causing them to emit visible light, ultraviolet light and even X-rays. Coronal mass ejections (CMEs) – in which large amounts of material from the corona are accelerated to such high speeds that they escape the Sun's gravity and hurtle out across the Solar System – are often, but not always, associated with flares and are probably triggered by a similar mechanism.

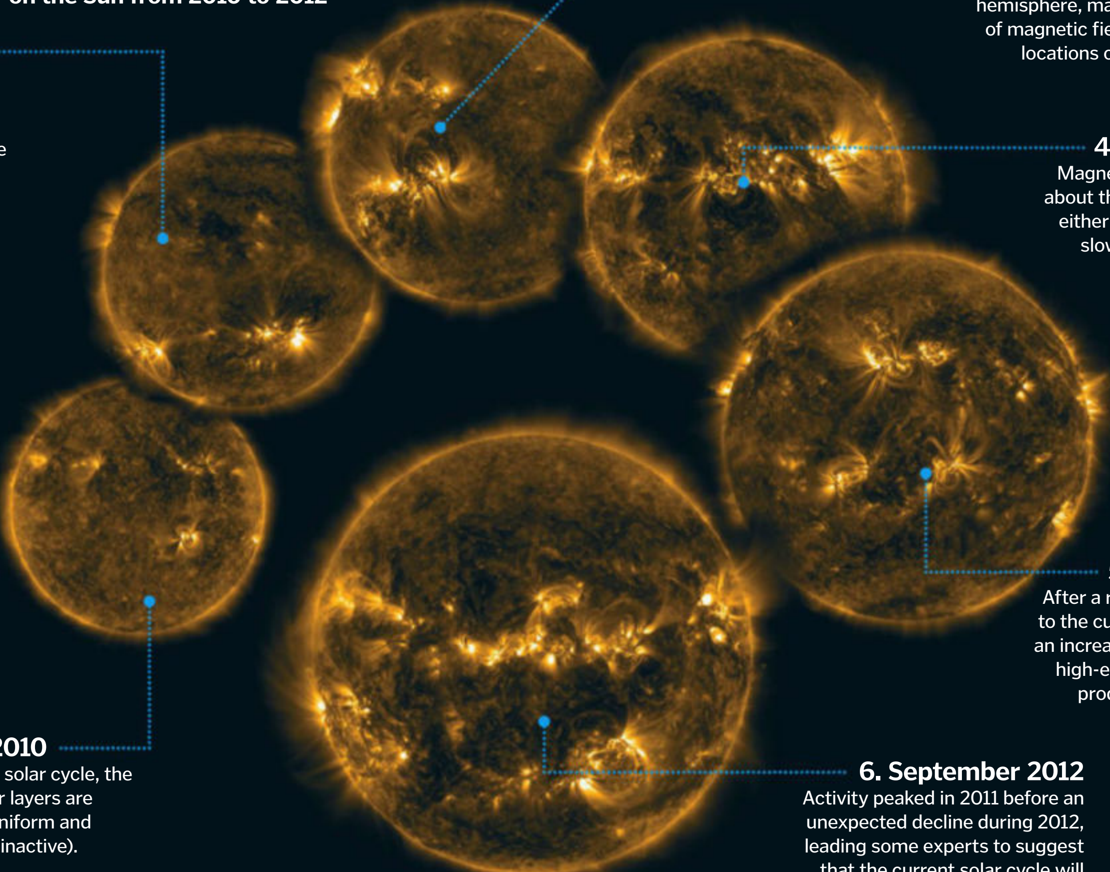
What role does magnetism play?

At the start of a solar cycle, an orderly magnetic field runs through the Sun some way beneath its surface, emerging near the poles. But because the Sun's equator spins faster than its polar regions, this field soon becomes 'wound up' around the equator. As it gets more tangled, magnetic loops are pushed out through the photosphere, creating sunspot pairs with one spot closer to the pole and another closer to the equator, opposite in polarity. Eventually, the field becomes so tangled up that magnetic regions on opposite sides of the equator start to cancel out. The field dwindles away to nothing, only to regenerate (with the opposite polarity) at the start of the next solar cycle after about 11 years.

> *"Telegraph systems went haywire, sometimes emitting visible sparks and giving their operators electric shocks"*

Maximum in progress

This sequence of images from the SDO satellite charts developing activity on the Sun from 2010 to 2012



revealed evidence for significant changes in its emission of ultraviolet radiation, which some think has the potential to affect Earth's climate.

Yet the solar maximum is just one phase in the overall solar cycle. At other times, the Sun is relatively quiet and free of sunspots and flares. The cycle was first documented in 1843 by German astronomer Samuel Heinrich Schwabe, after he spent 17 years recording the number and distribution of sunspots. Soon after, Swiss astronomer Johann Rudolf Wolf had traced the cycle as far back as 1745 using historical records, and introduced the numbering system that is still used to refer to different cycles.

Today the number and distribution of sunspots is often represented by the so-called 'butterfly diagram': the cycle starts off at solar minimum, with very few sunspots visible at fairly high latitudes on either side of the Sun's equator. Each individual spot may last a few days or weeks, but the pattern of distribution changes with time. Over several years, sunspots occur at lower latitudes and their number, size and intensity increase, reaching a peak at solar maximum. Over the next few years, as the spots draw closer to the equator, their numbers and intensity decline again.

Nobody really suspected that the sunspot cycle was accompanied by other activity until the mid-19th century, when Earth was buffeted by the biggest solar storm ever recorded.

English amateur astronomer Richard Carrington got the first hint of it on 1 September 1859, when he noted an intense white spot of light (what we'd now call a solar flare) on the disc of the Sun projected through his telescope onto a screen. Barely a day later, as clouds of material ejected from the Sun swept past Earth and interacted with our planet's magnetic field, intense auroras were seen all around the world. The northern lights (normally limited to polar skies) lit up the night as far south as the Caribbean, and people at higher latitudes were even able to read by the eerie glow.

The since-christened Carrington Event was an X-class solar flare (the most powerful type), accompanied by a coronal mass ejection (CME) – a wave of particles from the Sun's upper atmosphere superheated by the flare itself and directed straight towards Earth.

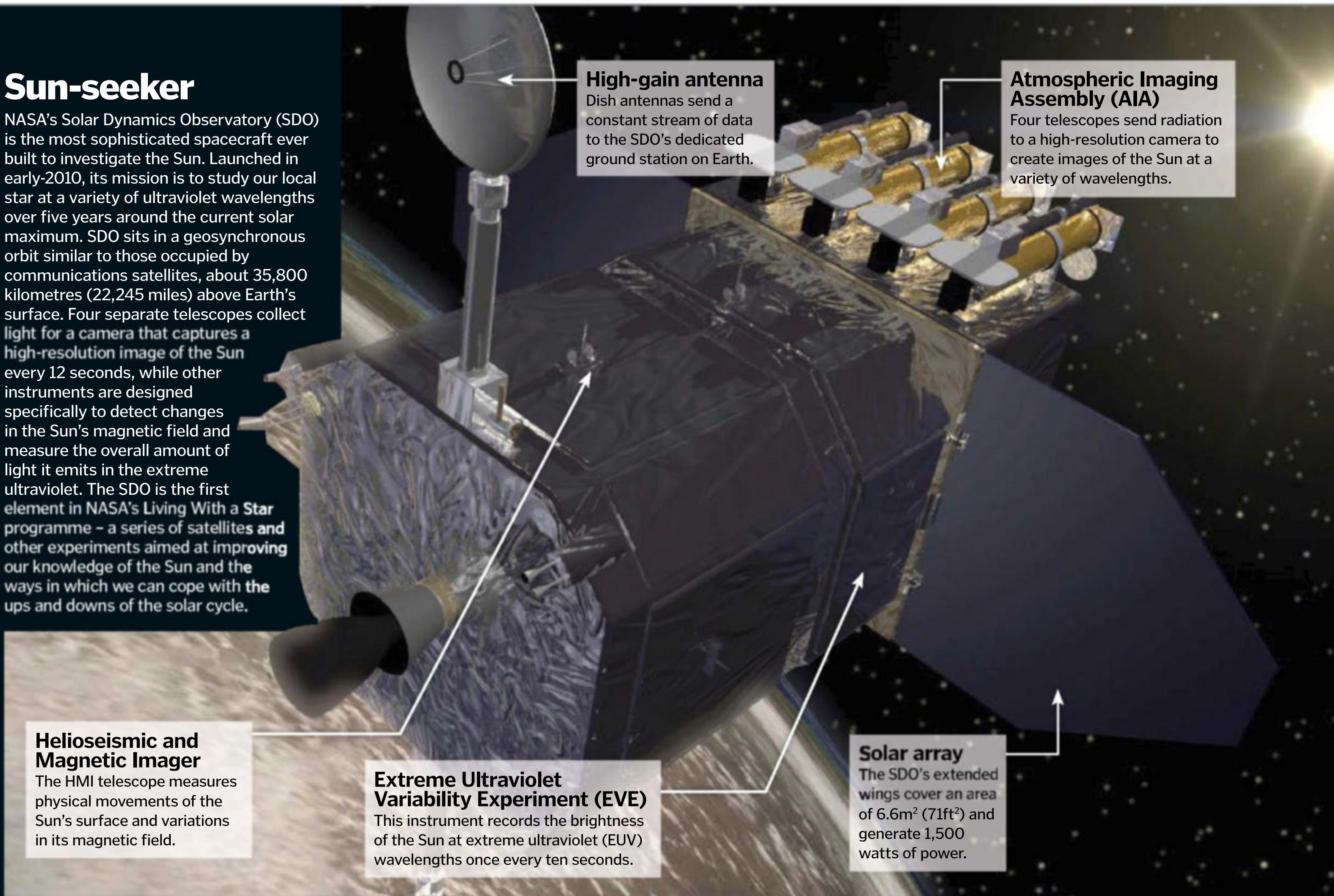
In addition to the spectacular light show, it also offered the first hint that solar storms could affect our technology even on the surface of Earth. Magnetometers picked up a sudden change in the magnetic field flowing through the atmosphere, and telegraph systems – the 19th-century equivalent of the internet, sending messages back and forth between Europe and America – suddenly went haywire, sometimes emitting visible sparks and giving their operators electric shocks. Not surprisingly, the Carrington Event is today acknowledged as the peak of a cycle (Solar Cycle 10).

Since Victorian times, we've learned a lot more about how the solar cycle works. In 1908, US astronomer George Ellery Hale showed that sunspots are associated with strong magnetic fields, and this proved to be the key to understanding the entire solar cycle.

DID YOU KNOW? NASA's SDO generates a CD's worth of information every 36 seconds

Sun-seeker

NASA's Solar Dynamics Observatory (SDO) is the most sophisticated spacecraft ever built to investigate the Sun. Launched in early-2010, its mission is to study our local star at a variety of ultraviolet wavelengths over five years around the current solar maximum. SDO sits in a geosynchronous orbit similar to those occupied by communications satellites, about 35,800 kilometres (22,245 miles) above Earth's surface. Four separate telescopes collect light for a camera that captures a high-resolution image of the Sun every 12 seconds, while other instruments are designed specifically to detect changes in the Sun's magnetic field and measure the overall amount of light it emits in the extreme ultraviolet. The SDO is the first element in NASA's Living With a Star programme – a series of satellites and other experiments aimed at improving our knowledge of the Sun and the ways in which we can cope with the ups and downs of the solar cycle.



Most solar activity, it seems, is associated with loops of the Sun's magnetic field emerging through the visible surface, or photosphere. Sunspots form at either end of these loops, and prominences are caused by relatively dense but cool gas flowing along them. Flares and CMEs are created when the loops become stretched and distended, and then 'short-circuit' closer to the surface, releasing huge amounts of excess energy. The magnetic loops themselves are forced out of the photosphere by the Sun's complex rotation; unlike Earth's magnetic field, which originates in the churning molten iron of our planet's core, solar magnetism is created a little way below the surface by swirling currents of electrically charged plasma.

Because it isn't a solid body, the Sun rotates differentially – that is, moving at different speeds at different latitudes. While the equatorial regions spin roughly every 25 days, the high latitudes around the poles move much more slowly, taking around 35 days. This ensures the solar magnetic field becomes tangled and disrupted (see magnetism boxout on page 25). With each solar cycle, a fresh magnetic field is created and destroyed, only to regenerate again. One side-effect of this is that the Sun's magnetism 'flips' with the completion of every solar cycle – some experts even consider the true solar cycle to be around 22 years long, since that's how long it takes for the Sun to return to its original state.

But although we now understand the essential causes of the cycle and the solar maximum, we certainly don't know everything – the Sun is unpredictable at the best of times, and solar maxima vary greatly in their intensity. The current solar cycle, for instance, seems to be one of the weakest on record, with relatively low numbers of sunspots, while the previous Solar Cycle 23 was far more intense and gave rise to some of the largest solar flares ever recorded – though fortunately they were mostly directed away from Earth.

Cycles can vary significantly in length too, by around two years on either side of the 11-year average, and can even produce double-maxima separated by a couple of years. And sometimes the cycle can stop altogether, as happened during a period of low activity from 1645-1715 known as the Maunder Minimum. This event coincided with a series of exceptionally cold northern-hemisphere winters, since referred to as the Little Ice Age – perhaps caused in part to less UV radiation from the Sun reaching Earth.

With the potentially dangerous effects of CMEs hitting our world, and the possibility that the solar cycle can alter Earth's climate, it's little wonder astronomers are eager to learn more about the Sun. Satellites like NASA's Solar Dynamics Observatory (SDO) are studying the current solar maximum in unprecedented detail, while others such as the twin Stereo spacecraft are designed to give advance warning of major flares and CMEs on the far side of the star. As we find out more about the influence solar outbursts can have on Earth, it's ever-more important to keep tabs on the weather forecast from space.

WIN PRIZES WORTH OVER £1,200

To celebrate the landmark 50th issue of How It Works, we're giving you the chance to win all this awesome stuff!*

Plus all this: One-year family pass to the London Transport Museum; family day pass to your choice of any English Heritage site across the UK; family day pass to INTECH Science Centre & Planetarium; one-year subscription to **How It Works** magazine

For your chance to take home all these amazing prizes, including Yamaha's award-winning AV receiver (the ideal central hub for your home cinema system), a super-stylish all-in-one aquarium from biOrb and a state-of-the-art mini PC simply head to the **How It Works** website at www.howitworksdaily.com and answer the following question:

Which of these inventions was first designed 50 years ago?

A) Printing press

B) Carbon nanotubes

C) Computer mouse

* T&Cs apply to some prizes so for full details please visit **www.howitworksdaily.com**. Closing date for entries is 15 September 2013.

5 TOP FACTS
NEPTUNE TRIVIA

Mini giant
1 Neptune is the smallest of the four gas giants in the Solar System, but despite being dwarfed by Uranus, it is more dense and therefore its mass is about 18 per cent greater.

Coldest planet
2 The temperature at the top of Neptune's clouds can drop to a chilly -225 degrees Celsius (-373 degrees Fahrenheit), making it the coldest planet in our Solar System.

Fleeting visit
3 Neptune has only been closely observed by spacecraft once, during NASA's Voyager 2 mission in 1989. NASA is investigating possibilities for future orbiter missions.

Earth-like gravity
4 A human weighing 65 kilograms (140 pounds) here on Earth would weigh just eight kilograms (17.5 pounds) more if it were possible to stand on Neptune's surface.

Diamond factory
5 The atmospheric pressure of Neptune is so great that hydrogen atoms break away from methane, leaving behind carbon, which is then compressed into diamonds.

DID YOU KNOW? *The heliosphere helps to protect the Solar System from harmful high-energy particles called cosmic rays*

The structure of Neptune

What lies beneath the surface of this blue ice giant in the outer Solar System?

Neptune's atmosphere is composed primarily of hydrogen and helium, and is incredibly stormy. Dark spots with high atmospheric pressure appear and disappear across Neptune as wispy cirrus clouds form and dissipate. Indeed, it plays host to the fastest winds of any planet in the Solar System – reaching speeds of around 2,000 kilometres (1,200 miles) per hour.

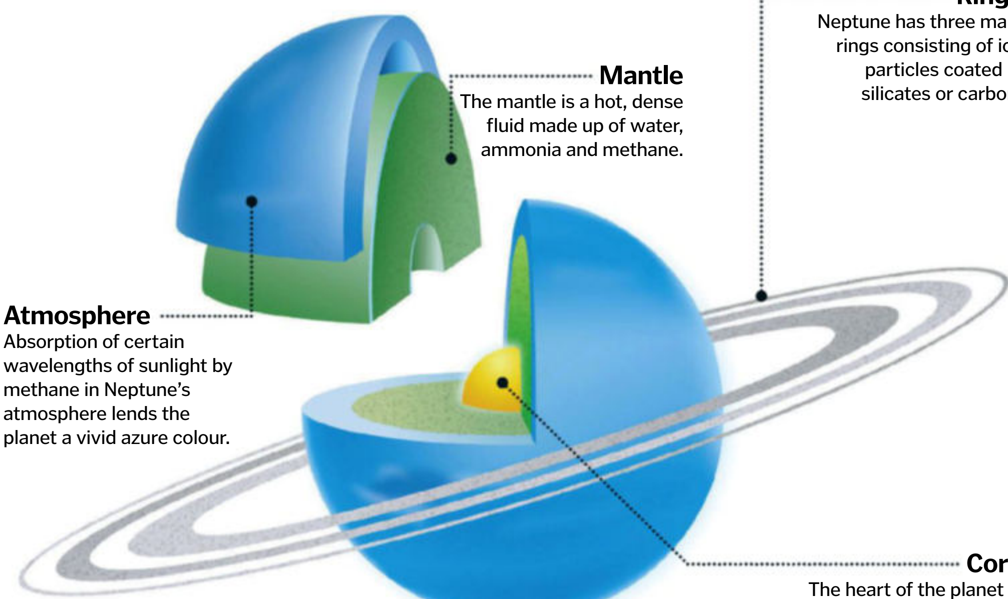
Like its neighbour, Uranus, Neptune has a deep atmosphere. The intense blue colour of both Uranus and Neptune is a result of the absorption of red light by methane in their atmospheres, but Neptune is much brighter, leading astronomers to suspect there is an additional factor at play contributing to its hue.

The atmosphere gradually merges with the mantle, which is composed of water, ammonia and methane ice – forming a thick slush that envelops the metal/ice core of the planet.

Neptune does not have a solid surface, so different regions rotate at different speeds. For example, at the equator a day is 18 hours long, while at the poles it is just 12 hours.

Neptune deconstructed

Below the gaseous atmosphere lies a dense metallic core, shrouded in an icy sea of methane…



Rings
Neptune has three main rings consisting of ice particles coated in silicates or carbon.

Mantle
The mantle is a hot, dense fluid made up of water, ammonia and methane.

Atmosphere
Absorption of certain wavelengths of sunlight by methane in Neptune's atmosphere lends the planet a vivid azure colour.

Core
The heart of the planet is metallic – composed of iron, nickel and silicates – and is estimated to have a mass similar to that of Earth.

Exploring the Solar System's outer edge

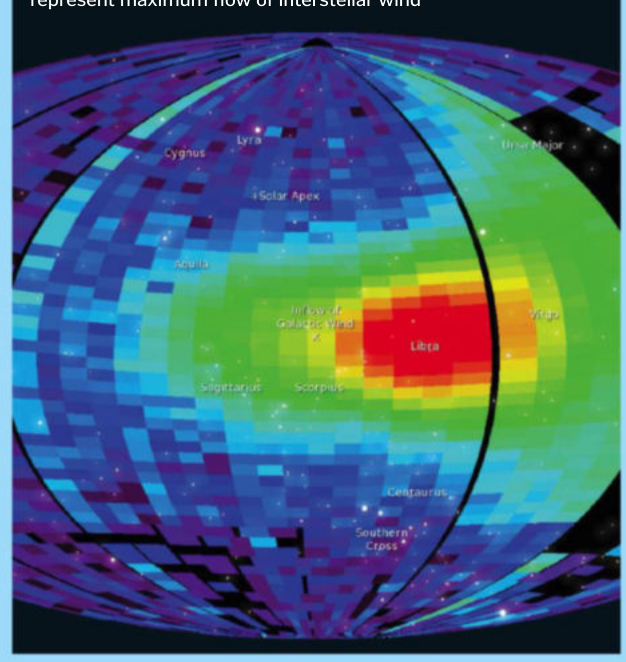
A trip to the final frontier before interstellar space

The interstellar boundary is the interface between the Solar System and interstellar space. Our Solar System is surrounded by a protective magnetic bubble generated by solar wind ejected from the Sun – this bubble is called the heliosphere.

At the very edges of the Solar System, the heliosphere collides with material from elsewhere in the galaxy. At this boundary, dangerous electrically charged particles moving towards us from interstellar space are deflected by the magnetic field, but neutral particles (with no charge) slip past and continue in towards the Sun. The particles that pass through give us clues about the composition of interstellar space and how it differs from our own protected magnetic bubble in the Milky Way.

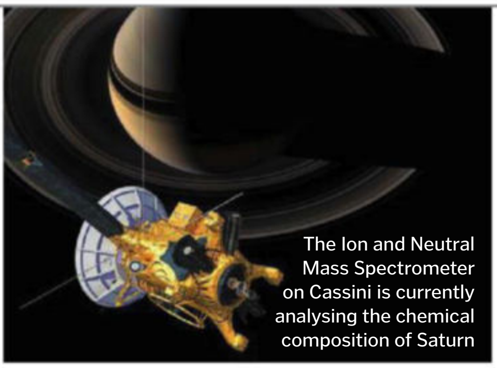
The Interstellar Boundary Explorer (IBEX) has been patrolling this border since 2009, intercepting the neutral atoms of galactic wind. It has shown that the chemical composition of our local bubble is very different from interstellar space. For example, our Solar System has significantly more oxygen than the interstellar medium. It is not yet known why, but this fundamental difference could provide clues as to how the Solar System and life were able to evolve.

IBEX is mapping the boundary between the Solar System and interstellar space – the red areas represent maximum flow of interstellar wind



> "Prior to analysis, the sample must be vaporised and ionised – ie turned into a gas and given an electrical charge"

How do we identify chemicals in space?



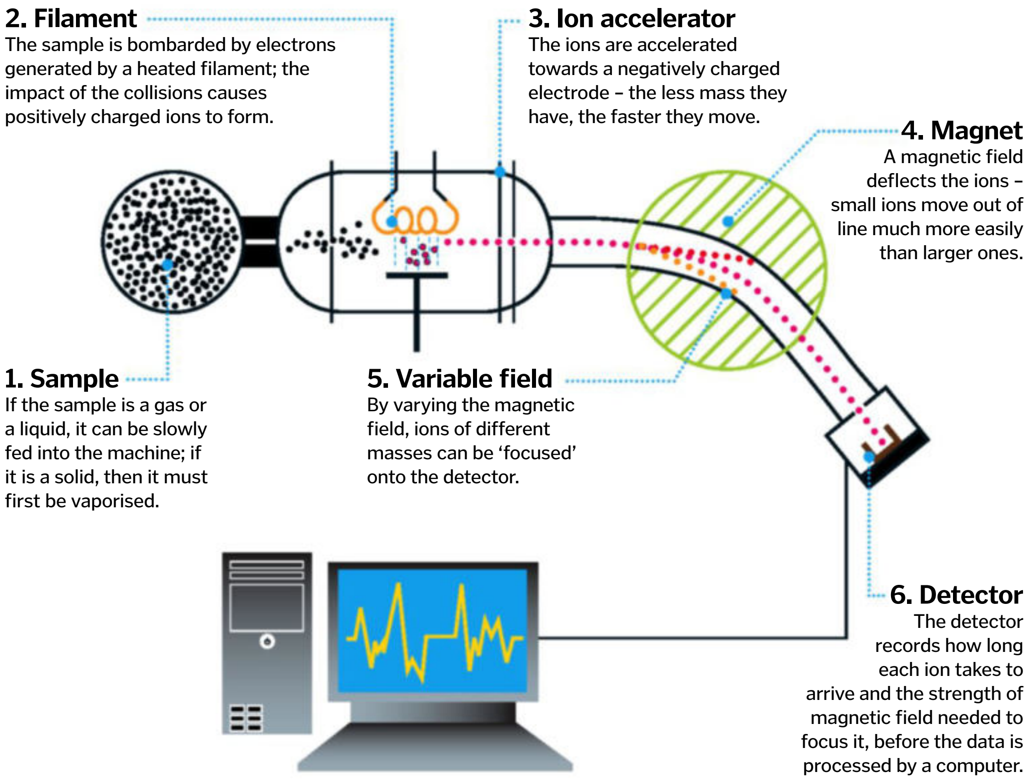
The Ion and Neutral Mass Spectrometer on Cassini is currently analysing the chemical composition of Saturn

With a mass spectrometer, astronomers can deduce the composition of alien worlds using just their mass…

Mass spectrometry enables scientists to measure the mass of molecules in a sample, and from this its chemical makeup. They are increasingly being included in the arsenal of technology on spacecraft to identify the unknown chemical composition of the Solar System. An instrument on NASA's Curiosity rover, for instance, is currently being used to scrutinise Martian rock.

Prior to analysis, the sample must be vaporised and ionised – ie turned into a gas and given an electrical charge. The machine uses the positive charge to sort the ions according to their molecular mass. A negatively charged plate attracts the positively charged ions, which move at different speeds relative to their mass – the larger the molecule, the slower it will move. Similarly, when subjected to the magnetic field, smaller molecules are deflected more by the magnet than larger ones.

The acceleration and deflection separates the molecules in time and space, allowing the machine to determine their mass and therefore establish a sample's chemical structure.



Mercury's orbit

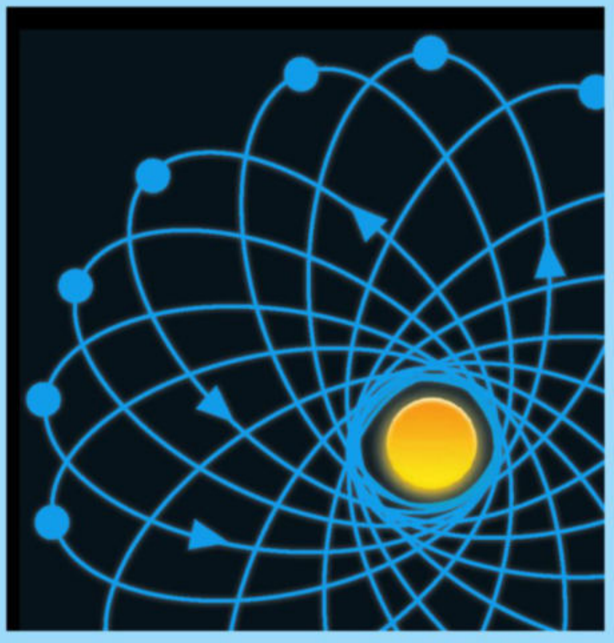
The Solar System's innermost planet travels through a curvature in the fabric of space-time

Of all the Solar System's planets, Mercury has the most eccentric orbit. Moving in an ellipse its distance from the Sun varies from 46 million kilometres (28.6 million miles) to 70 million kilometres (43.5 million miles) across its orbital cycle.

Not only does Mercury travel in an ellipse, but the planet's closest approach to the Sun is not always in the same place. Mercury's orbit drifts, with each ellipse around the Sun seeing it move along slightly, tracing a shape similar to the petals of a daisy (see picture).

This drifting is partially caused by the gravitational pull of local bodies; the Sun, of course, has the most influence, but other planets and asteroid belts also have an effect, dictating its path.

However only part of the drift is accounted for by other objects' gravity near Mercury. The orbit can only be fully explained by Einstein's general theory of relativity. The Sun's gravitational field distorts the fabric of space and time, forming a curvature. This distorted space geometry also affects the route Mercury takes around the Sun.



"As the arms of spiral galaxies age they turn from blue to red and on to yellow (dying stars)"

Spiral galaxies

Discover why our own galaxy and around 70 per cent of our closest neighbours are twisted into the shape of a pinwheel

Tens of thousands of light years in diameter, spiral galaxies revolve around a central point. The farther away from the centre of the galaxy, the longer the material takes to rotate, causing it to wind up into a spiral as the galaxy spins.

The spiral structure is the result of a density wave, which passes out of the centre of the galaxy through the clouds of dust that make up the disc. This wave compresses hydrogen gas as it moves through the disc, forming dust lanes and triggering nuclear fusion. In the wave's wake, new stars develop. As the arms of spiral galaxies age they turn from blue (young stars) to red (old stars) and on to yellow (dying stars); the latter are also called 'fossil arms'.

Spiral galaxies turn very slowly, taking hundreds of millions of years to complete a full rotation – our own galaxy, the Milky Way, for instance, takes approximately 250 million years to turn 360 degrees on its central axis.

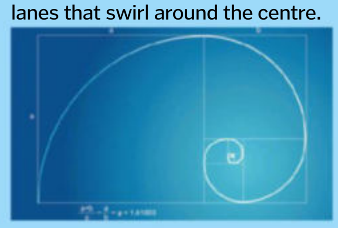
At the core of a spiral galaxy is the galactic bulge, a densely packed population of stars that tend to be older – and so redder. It is predicted that the centre of most spiral galaxies also plays host to a supermassive black hole, billions of solar masses in size. They grow by pulling in matter from the galaxy, and dictate the rotation and orbits of all the stars around them.

Spiral galaxies have such huge gravitational pull that they trap a spherical halo of stars and globular star clusters (groups of stars that orbit the galaxy like satellites). These may have formed within the galaxy itself or been stolen from neighbouring galaxies as they collide and merge. These are particularly visible when observing galaxies from the side, and form a hazy cloud that encircles the central disc.

Maths in space

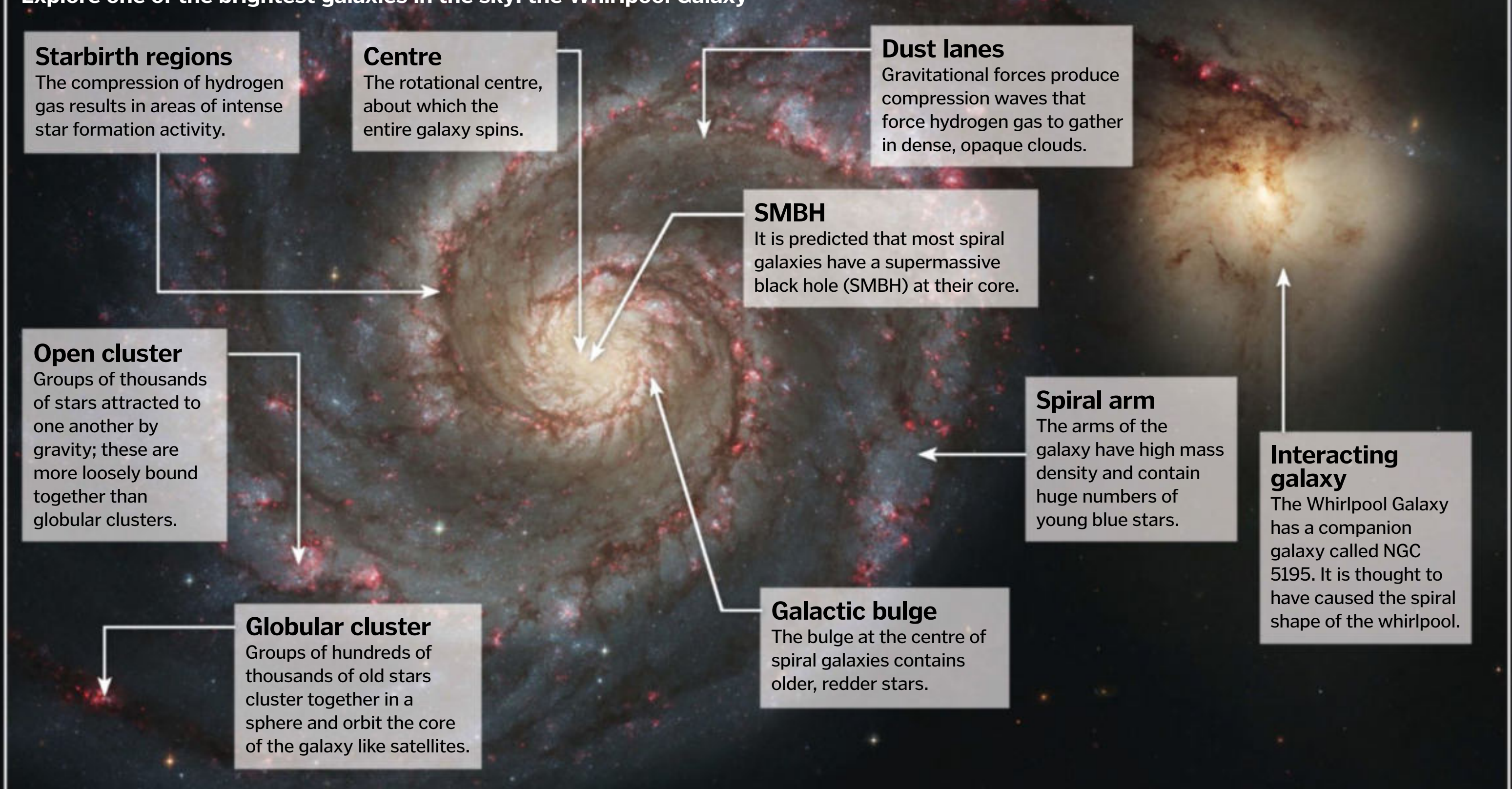
The spiral arms of galaxies are logarithmic; the turns are not a fixed distance from one another – rather the distance between them increases exponentially. A spiral of this pattern allows the galaxy to grow without changing shape.

The Fibonacci sequence (0, 1, 1, 2, 3, 5, 8, 13, etc) is made by adding together the two previous numbers to get the next one. It has long been known that Fibonacci sequences occur in nature, describing the arrangement of leaves on a stem and the petals on a flower, etc. Using tiled squares of sizes following the Fibonacci sequence, a spiral can be drawn (see below). Intriguingly, this ratio can be superimposed over the spiral arms of some galaxies, mapping the trajectory of the dust lanes that swirl around the centre.



Getting in a whirl...

Explore one of the brightest galaxies in the sky: the Whirlpool Galaxy



THE STATS
MILKY WAY

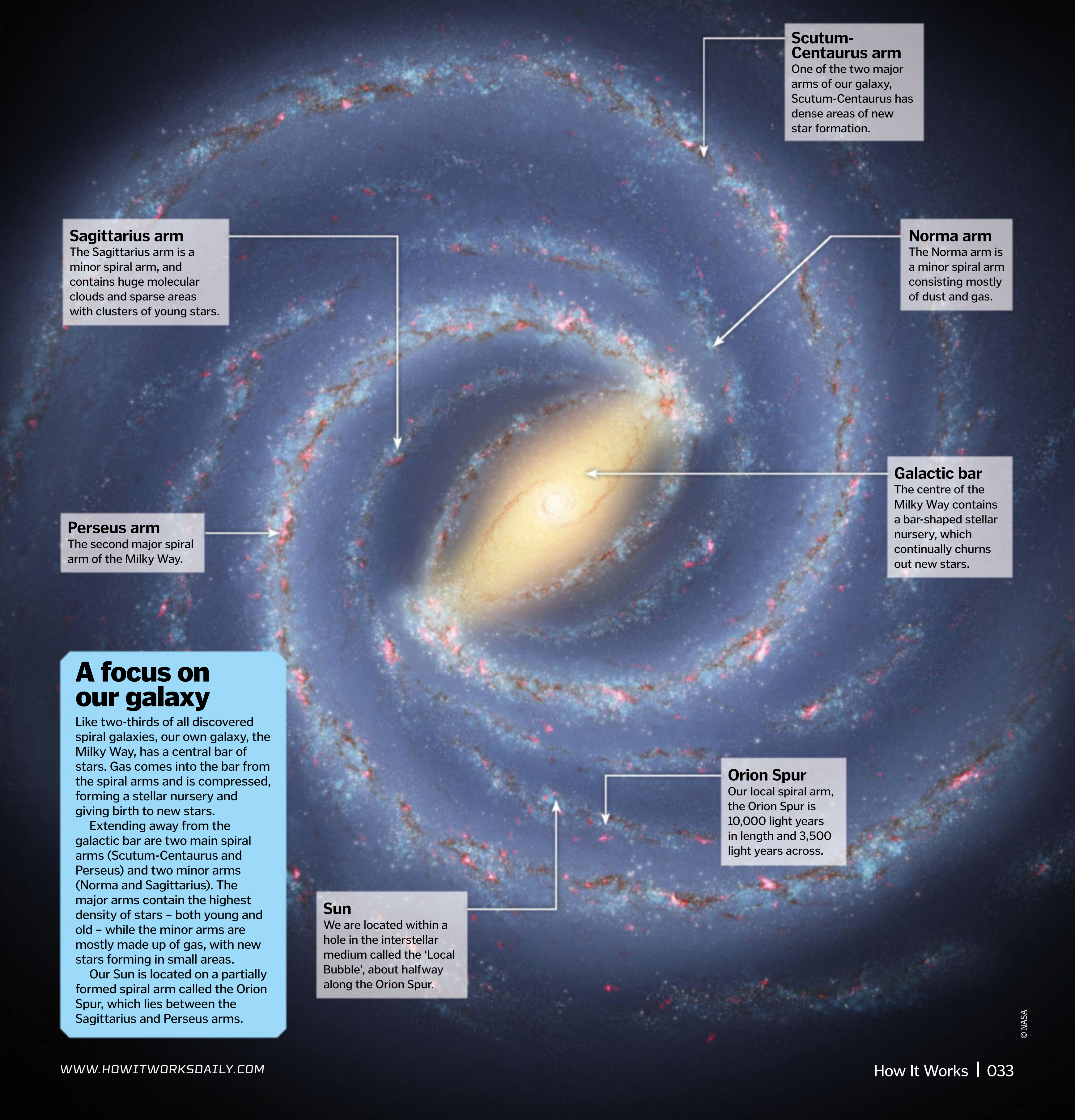
DIAMETER 120,000LY | MAJOR ARMS 2 | OLDEST STAR (YRS) 13bn

NUMBER OF STARS 200-400bn | MINOR ARMS 2 | THICKNESS 1,000LY

DID YOU KNOW? At the centre of the Milky Way is a supermassive black hole known as Sagittarius A*

Unravelling the Milky Way

Where do we fit within the most well-known spiral galaxy in the universe?



A focus on our galaxy

Like two-thirds of all discovered spiral galaxies, our own galaxy, the Milky Way, has a central bar of stars. Gas comes into the bar from the spiral arms and is compressed, forming a stellar nursery and giving birth to new stars.

Extending away from the galactic bar are two main spiral arms (Scutum-Centaurus and Perseus) and two minor arms (Norma and Sagittarius). The major arms contain the highest density of stars – both young and old – while the minor arms are mostly made up of gas, with new stars forming in small areas.

Our Sun is located on a partially formed spiral arm called the Orion Spur, which lies between the Sagittarius and Perseus arms.

THE DEADLIEST PLACES ON EARTH

It may be our home, but this world can be a very hostile place…

Humans are an exceptionally adaptable species. We have colonised every continent on Earth and made a home for ourselves in almost all environments. We have used technology to protect our fragile bodies from the elements and built shelters to withstand the seasons. It's easy to fool ourselves that we've tamed our planet…

But the reality is that we live within the thinnest film of habitability, painted onto the surface of an otherwise lethal sphere. Travel just 32 kilometres (20 miles) straight down and the temperature rises to 800 degrees Celsius (1,472 degrees Fahrenheit). The same distance in the opposite direction would leave you exposed to temperatures well below freezing and gasping for breath. To put that in context, imagine living in Reading and knowing that a trip to London in one direction, or Swindon in the other, would mean certain death.

Even on the surface, there are pockets we haven't yet managed to master. There's no technology to hold back a volcano, or to stop the sea from rising. A medium-sized volcano such as the 1980 eruption of Mount St Helens, WA, releases as much energy as 20,000 Hiroshima bombs. And a volcano doesn't even need to erupt to be lethal. The steady accumulation of poisonous gas dissolving into lake water is like trickle charging a battery. Eventually the system becomes so unstable that it discharges all at once. Environments like these are especially dangerous precisely because of their unpredictability. The bottom of the ocean and the top of a mountain are deadly all year round. When we travel there, we go prepared and we don't stay long. But a volcano is just a hillside until it erupts and a low-lying island is a tropical paradise until a tsunami or freak high tide engulfs it. So delicate humanity crosses its fingers and settles down to live in the shadow of a simmering catastrophe.

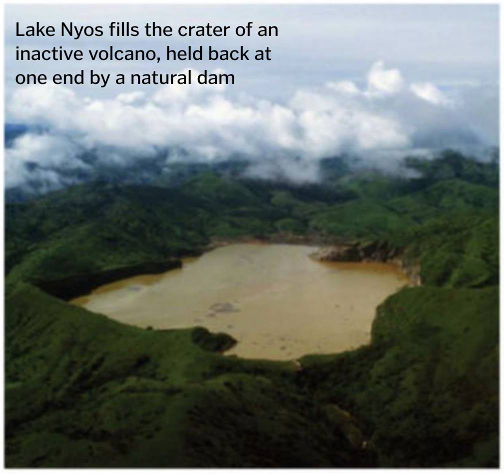
In this feature, we focus on some of the most naturally dangerous places to live in the world, along with a few that humans have made for themselves. And the extraordinary thing is that none of them are deserted. People live and/or work in every one. In fact, some of the most deadly ones are actually tourist destinations! Are we such a successful species *despite* our taste for danger, or *because* of it?

THE STATS
CAVE OF CRYSTALS

DEPTH 300m | YEAR DISCOVERED 2000 | HUMIDITY 90-100%
LENGTH 27m | TEMPERATURE 58°C | LARGEST CRYSTAL 55 tons

DID YOU KNOW? Heavy rain can turn the ash from a pyroclastic flow into a second deluge of mud called a lahar

Tapping the natural gas in Lake Kivu could double Rwanda's electricity generation capacity



Lake Nyos fills the crater of an inactive volcano, held back at one end by a natural dam

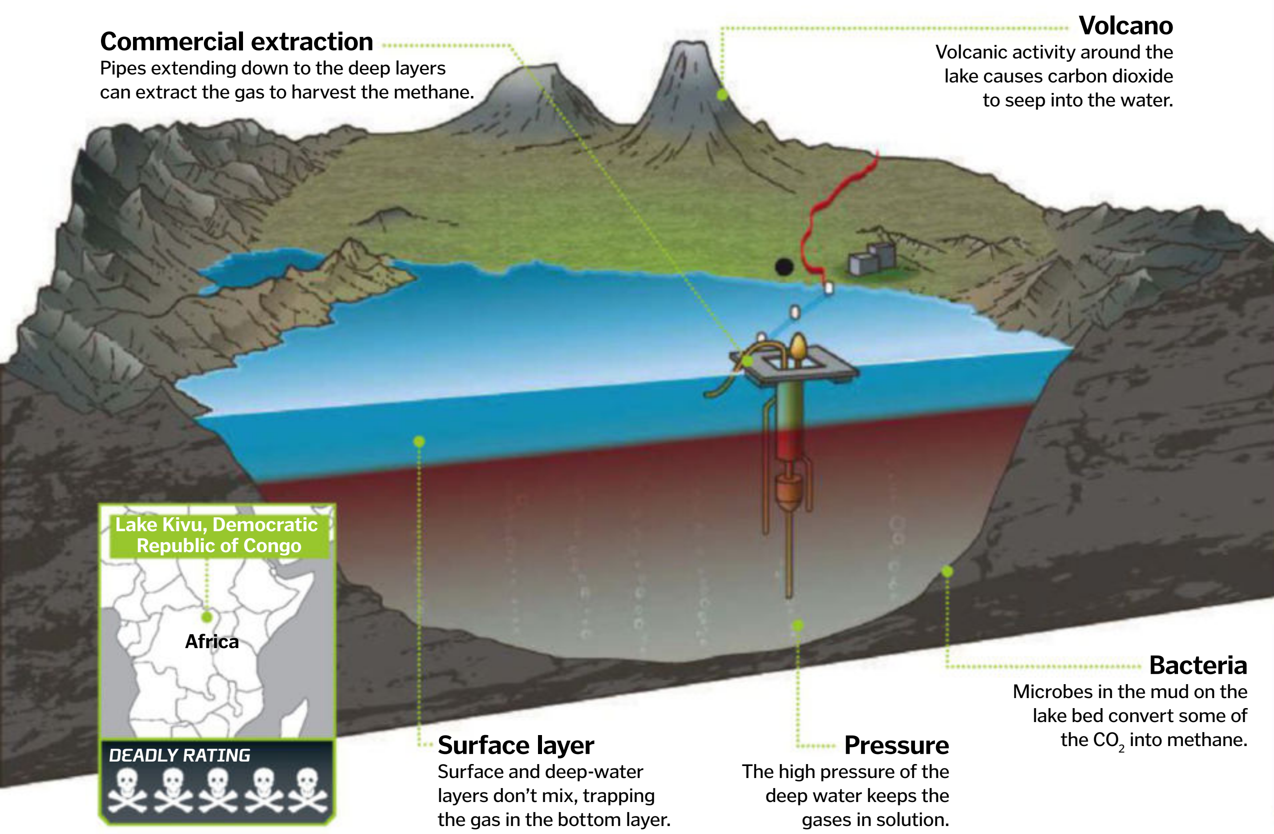
The world's most explosive lake

Lake Kivu is a freshwater lake sitting on a volcanically active rift valley. It is extremely deep – at its deepest point, you could balance St Paul's Cathedral on top of the London Shard and still have plenty of room to the surface. Trapped in its deepest layers are around 256 cubic kilometres (61 cubic miles) of dissolved carbon dioxide and another 65 cubic kilometres (15.5 cubic miles) of dissolved methane.

This huge volume of gas is only held there because the deep waters of the lake don't normally mix with the surface layers. But a volcanic eruption could trigger a runaway event that brings all the gas out of solution at once. This happened in 1986 at Lake Nyos in Cameroon. On that occasion, a cloud of invisible carbon dioxide gas rolled out of the lake and down the hillside at about 50 kilometres (30 miles) per hour. Because CO_2 is heavier than air, it displaces the breathable air close to the ground. Tragically, more than 1,700 people suffocated to death in a killing zone that extended around 25 kilometres (16 miles) from the lake.

Worryingly, the same thing could happen at Lake Kivu, except on a much larger scale. Not only could the amount of released gas be over 300 times greater, but there are 2 million people living on the shores of the lake.

What turns a lake into a time bomb?



Hells of our own making

1 Chernobyl Exclusion Zone, Ukraine

After the famous reactor meltdown of 1986, the Ukrainian government established a 30-kilometre (19-mile) perimeter around the power plant. The most radioactively contaminated place in the world, officials estimate the exclusion zone won't be safe for 20,000 years.

2 Derweze gas crater, Turkmenistan

In 1971 a drilling rig collapsed over a natural gas field in the Karakum Desert. Geologists set fire to it to try and burn off the escaping gas. Little did they know that the 70-metre (230-foot) hole would still be burning 42 years later!

3 Beijing, China

Seven of the ten most polluted cities are in China and the capital, Beijing, is one of the worst. Air pollutant levels of 886 micrograms per cubic metre were measured this year. London's average is 14.

4 Dzerzhinsk, Russia

Nearly 300,000 tons of chemical waste were dumped in this former Soviet chemical weapons manufacturing town. The average male life expectancy there is just 42.

5 San Pedro Sula, Honduras

Ranking as the most violent place in the world in both 2011 and 2012, San Pedro Sula has an average of 173 homicides per 100,000 residents – that equates to roughly three per day!

“At current rates of sea level rise, the Maldives could be totally submerged by 2100”

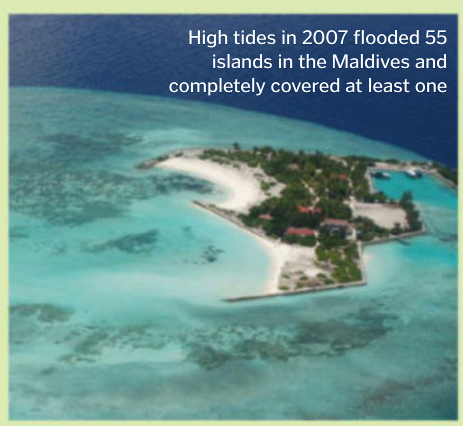
Earth’s hottest air temperature

Most caves have a constant, cool temperature, isolated from the fluctuations on the surface. But in the Mexican town of Naica, there is a cave complex where the air temperature is higher than the highest temperature ever recorded in Death Valley, California! Worse still, the Cave of Crystals (or Cueva de los Cristales) is connected to flooded chambers and must be constantly pumped to keep it drained. This means that humidity is almost 100 per cent; sweating has absolutely no effect. In fact, since the air in your lungs is cooler than the air you breathe in, water tends to condense in them, which leads to progressive respiratory failure. Geologists studying the cave wear respirators and special suits with a network of tubes that circulate water cooled by ice in a backpack. This allows them to work for 20-30 minutes at a time. Without this protection, you would collapse from heat stroke and die within ten or so minutes.

The largest of the crystals began forming 600,000 years ago

Earth’s lowest country

The Republic of the Maldives is the world’s lowest country. An archipelago of over a thousand islands – clustered into 26 coral atolls – the highest point is just 2.4 metres (7.9 feet) above sea level and 80 per cent of the land area is less than a metre (3.3 feet) above the ocean. The 2004 tsunami caused damage equivalent to over 60 per cent of the nation’s GDP and 14 islands had to be evacuated; this was despite the fact that it struck at low tide. Even without tsunamis, the Maldives are doomed. At current rates of sea level rise, the entire country could be submerged by 2100. Mining the coral reefs for use in the construction industry is only exacerbating the problem, by removing the sole natural protection from the waves.



High tides in 2007 flooded 55 islands in the Maldives and completely covered at least one

The coldest place in the world

Vostok Station in the Antarctic is high up, completely dry and unbelievably cold. Average winter temperatures are around -65 degrees Celsius (-85 degrees Fahrenheit) and the lowest temperature ever recorded is -89.2 degrees Celsius (-128.6 degrees Fahrenheit); that’s cold enough to freeze the carbon dioxide in your breath! As well as the incredibly low temperature, Vostok’s high altitude of 3,488 metres (11,444 feet) means that the air is very thin and the humidity is zero; Antarctica is, in fact, a cold desert. In combination, these conditions cause headaches, nosebleeds, blood pressure rises, vomiting, muscle pain, earache and a sense of suffocation. Symptoms can develop within minutes of arriving in some cases and, if the victim isn’t immediately evacuated, they can die of pulmonary oedema. Even for hardier individuals, the acclimatisation process can take up to two months of suffering and most people typically lose about 4.5 kilograms (ten pounds) in body weight.

STRANGE BUT TRUE
GO WITH THE FLOW

What happens when a pyroclastic flow hits water?

A It stops **B** It accelerates **C** It reverses uphill

Answer:
When the mass of red-hot ash and stones hits a river, the heavier rocks sink and boil the water. The steam mixes with the lighter ash and causes it to surge along the riverbed at an even faster pace.

DID YOU KNOW? Vostok Station in Antarctica experiences a polar night that lasts for 120 days, from April to August

Indonesia's most active volcano

There are 129 volcanoes in Indonesia but Merapi is the most active; smoke rises from the summit 300 days out of every 365. It is classed as a stratovolcano, with very steep sides built from the debris of previous eruptions, and the vent is plugged by a dome of solid lava. The steep sides mean that the dome is balanced precariously and minor quakes can cause it to fracture or collapse. When that happens clouds of rock ash and superheated gas can spew out and roll down the hillside at over 113 kilometres (70 miles) per hour. These pyroclastic flows can travel 24 kilometres (15 miles) from the volcano, incinerating anything in their path. In 2010, a series of eruptions produced a cloud of ash that reached 12 kilometres (7.5 miles) high.

Mount Merapi erupts every two to three years with larger eruptions every 10-15 years

Anatomy of a stratovolcano

Volcanic bombs
Lumps of molten rock up to 5m (16ft) across are flung into the air and harden into deadly missiles in flight.

Vents
As the pressure builds, the lava dome may blow or secondary vents may force themselves through the sides.

Steep sides
The lava from a stratovolcano is viscous and doesn't travel far, so the sides build up steeply.

Pyroclastic flow
Heavier ash and superhot rock fragments can't rise with the ash plume and instead roll down the side of the volcano.

Magma chamber
A reservoir of magma 1.6km (1mi) below the surface pushes upwards against the lava dome that seals the top.

Worst holiday destinations

1 Panabaj, Guatemala

Heavy rains, steep hillsides and frequent earthquakes make this region especially prone to mudslides. In 2005, more than 900 mudslides were triggered throughout Central America by Hurricane Stan. The village of Panabaj was buried with at least 300 killed.

2 Atacama Desert, Chile

The driest place on Earth. Some of the weather stations there have never recorded rain and certain riverbeds may have been dry for 120,000 years. NASA uses the Atacama to train for Mars missions.

3 Ilha da Queimada Grande, Brazil

Nicknamed Snake Island, this island off the coast of São Paulo is teeming with one of the most venomous snakes on Earth: the golden lancehead.

4 Yungas Road, Bolivia

The 'Road of Death' winds through dense rainforest, prone to fog and landslips. With no guard rail to save you from the 600-metre (1,970-foot) sheer drop, this road claims 200-300 lives each year.

5 Miyakejima, Japan

This volcanic island off Tokyo, Japan, has the highest concentration of poisonous gas leaking from the ground. It's so dangerous that the island was evacuated in 2000 for five years, and residents must still carry gas masks at all times.

"When yellow-pigmented feathers overlay those with blue-reflecting properties plumage will look green"

How feathers work

A bird's plumage performs many different roles – not least flight, defence, sensory reception and egg incubation

All birds have feathers – and *only* birds have feathers. In fact, some species can have over 25,000, including long flight feathers, insulating downy feathers and stiff tail feathers that act like rudders.

While they obviously facilitate flight – by forming the airfoil shape that generates lift as air flows over the wing – feathers serve a great many other roles. Birds are among the most magnificently decorated creatures on Earth and they use their handsome colours to attract mates, ward off predators and also to remain unseen by blending in with the background.

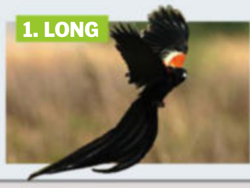
Birds display different plumage depending on their age, sex and seasonal changes. They see in colour and the plumage of a male has a dramatic effect on how attractive he is to the female, which impacts on mating success. It works both ways as the males of some species judge the health of a female by her feathers.

Most of the colours are the result of chemical pigments – eg melanin, carotenoids and porphyrins – produced in the feathers as they grow. Other colours can be caused by refraction of light due to feather structure. Spectacular colours can also be made by a combination of the two; for instance, when yellow-pigmented feathers overlay those with blue-reflecting properties, the plumage will look green.

Some birds use these colours as camouflage. Depending on the season, a bird's hormones can instruct it to shed (moult) its old feathers and grow a new set more suited to the current environment. Birds from snowy regions may be pure white in winter, but – after a moult – often regrow brighter or patterned feathers to better match the summer environment.

Birds also moult regularly in order to renew any damaged feathers because they cannot heal themselves. A moult can be total or partial during which time the damaged feather will be replaced. However if an individual feather has fallen out altogether, it will start growing a new one straight away. Growing new feathers requires a lot of the bird's energy, though, so a complete or partial moult will never coincide with demanding events in the year like breeding, nesting or migration.

HEAD 2 HEAD
LONG TAILS



1. LONG

Long-tailed widowbird
With a 50-centimetre (20-inch)-long tail, it has been proven that when its tail feathers are docked females are less interested.

2. LONGER

Quetzal
During mating season, the males of this species from the rainforests of Central America grow two extra tail feathers that reach up to a metre (3.3 feet) long.

3. LONGEST

Onagadori
This is a Japanese breed of chicken, the cockerel of which can grow very long tail feathers – over ten metres (32 feet) in some cases – due to a mutation.

DID YOU KNOW? *By vibrating its wings twice as fast as a hummingbird the club-winged manakin makes a noise like a violin*

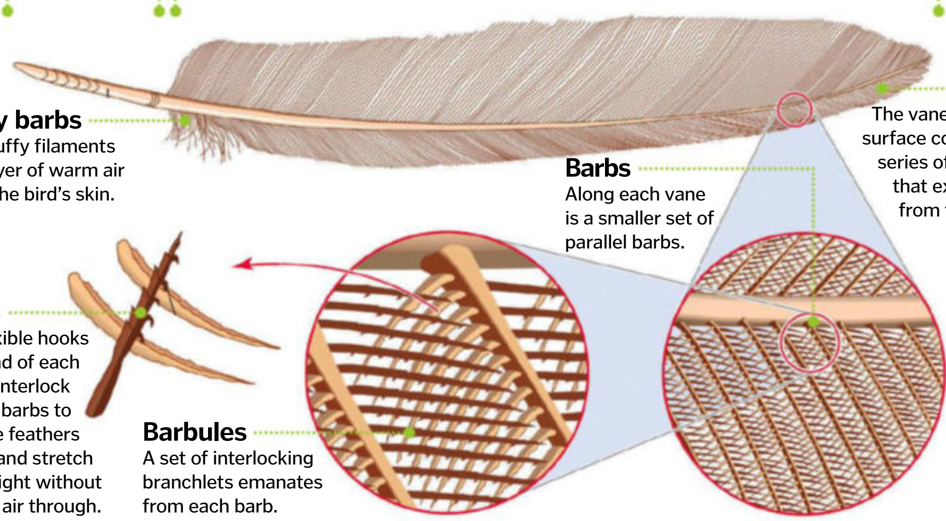
Parts of a feather

A feather may look like a single blade but it actually comprises many important features

Central shaft
The main stem of a feather is divided into two parts: the calamus and the rachis. The outer side of the vanes is on the leading edge.

Calamus
Also called the quill, the horny calamus is the hollow part of the feather nearest the body with no vanes.

Rachis
The region at the distal end of the feather is the solid rachis, along which hundreds of tiny strands called vanes offshoot.



Downy barbs
These fluffy filaments trap a layer of warm air next to the bird's skin.

Vanes
The vane is the flat surface covered in a series of branches that extends out from the rachis.

Barbs
Along each vane is a smaller set of parallel barbs.

Hooks
Tiny, flexible hooks at the end of each barbule interlock with the barbs to allow the feathers to bend and stretch during flight without allowing air through.

Barbules
A set of interlocking branchlets emanates from each barb.

How does a feather grow?

Feathers are attached to the bird along regularly spaced tracts known as pterylae that cover almost the entire body; areas without feather tracts are called apteria. Growth begins beneath the surface of the skin in pimples called papillae, which capillaries supply with blood. The feather grows from a follicle – similar to hair – which forms when cells multiply in a ring shape.

Keratin cells harden the epidermis and concentrate the number of cells in the dermis. The keratinocytes continue to multiply in a ring shape, pushing old cells upwards while creating new cells at the base, until a tube pushes towards the skin's surface. A softer vane sheath, meanwhile, provides a protective barrier for the growing tube. The epidermal layer then splits into what will become the barbs. Before the feather emerges through the skin the barbs are curled around the tube. The opening at the base, where blood enters, is sealed off once the feather is fully grown.

Which feathers do what?

Discover the key types of feather on a bird that help it fly

Contour feathers
Controlled by special muscles, these outer feathers give the bird its streamlined shape. They have soft filaments at the base but flattened ends that lie on top of each other like roof tiles to keep the bird aerodynamic.

Covert feathers
These smaller feathers, known as tectrices, are positioned in rows over the base of the flight feathers to smooth airflow over the wings and provide insulation.

Wing flight feathers
The primary, secondary and tertiary flight feathers of the wings (remiges) are attached to the bone by ligaments. Used for steering, the primaries are the longest and strongest of the remiges. Secondaries, meanwhile, help the bird to flap and dive.

Tail feathers
These long and stiff feathers, called rectrices, help the bird steer during flight, granting stability and balance.

STRANGE BUT TRUE

KIWI QUIRK

What's unusual about New Zealand's North Island?

A It has no name **B** It's sinking **C** It's a desert

Answer:
The New Zealand Geographic Board recently made the shock discovery that neither of New Zealand's islands has an official English name. Plans are afoot to name the islands North Island and South Island, together with their respective original Maori monikers: Te Ika-a-Maui and Te Waipounamu.

DID YOU KNOW? *It takes Waitomo's stalactites around 100 years to grow by just one cubic centimetre*

Explore the Waitomo glowworm caves

Discover New Zealand's beautiful secret grottoes and the colourful bugs that lay sticky traps on the ceiling

To the north-east of Mount Taranaki on New Zealand's North Island is a series of limestone caves filled with dramatic spiky mineral deposits. Around 30 million years ago much of New Zealand was underwater. Over time, however, the calcareous remains of marine organisms were compressed under layers of mud and sand to form sedimentary limestone. Tectonic forces later lifted the rock above sea level to create islands. Volcanic activity then caused the formation of around 300 limestone caverns now known as the Waitomo Caves.

For millions of years, acidic groundwater percolated through the overlying limestone rock and dripped from the ceiling of the caves. This carried mineral deposits out of the rock, which formed the icicle-shaped stalactites that hang from the ceiling. The similar stalagmites that emerge from the ground also developed wherever the drips landed.

The Waitomo Caves are not only spectacular geologically, they also boast some striking inhabitants: glowworms (Arachnocampa luminosa). The larva of the fungus gnat is a luminous insect that hangs on silk from the roof of the caves and glows bright blue/green. The glow, which is the result of phosphorescent chemicals from the bug's intestine, is used to attract mayflies that enter the cave to mate.

The worms spin a network of silk threads across the rocky ceiling so they can move around with ease. Then, at different intervals, they create individual threads that dangle down and are covered in sticky mucus. Mayflies, attracted by the glow from the worms, fly up to the ceiling where they become entangled in the sticky traps. When a victim has been ensnared the worm switches off its light (to conserve energy) and hurries along the silk pathways to feast on the prey. The more danglers the glowworms make the more chance they have of capturing lunch.

> "Ice sheets around 1.6km (1mi) thick have buried 98 per cent of the continent for over 25 million years"

Antarctica's secret land

Most of the last unexplored continent is hidden – discover its geography now

Antarctica, Earth's fifth-largest continent, has scenery as dramatic as America's Great Lakes or the European Alps, yet its mountains and lakes are as uncharted as Mars. Ice sheets around 1.6 kilometres (one mile) thick have buried 98 per cent of the continent for more than 25 million years.

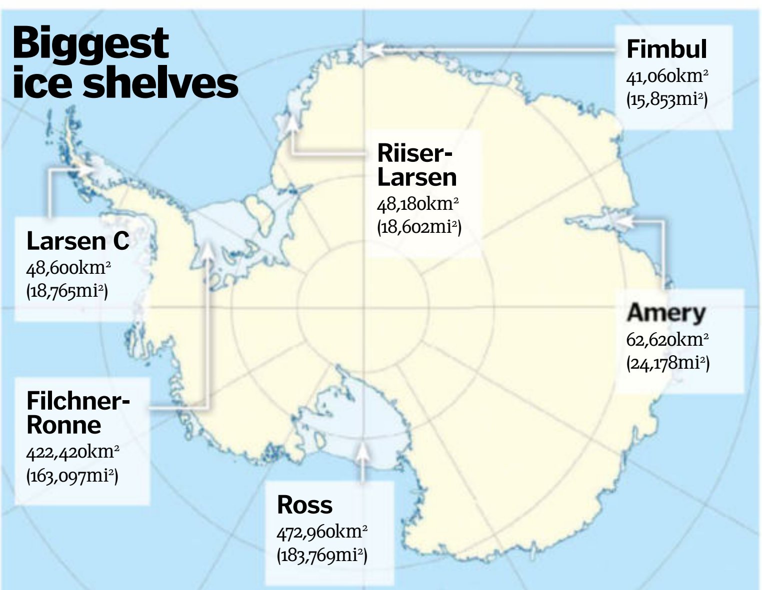
The continent began to freeze over 34 million years ago when atmospheric carbon dioxide levels plummeted. Antarctica's climate cooled and snow failed to melt on the Gamburtsev Mountains. Over thousands of years, fresh snowfall crushed air from the snow, turning it into dense ice. The ice moved downhill under its own weight as glaciers, and then these grew and merged into gigantic ice sheets.

The ice in Antarctica's interior is frozen to the bedrock and moves at a mere two metres (6.6 feet) per year. But near the coast, water and soft, flexible sediment lubricate the ice to form fast-moving channels called ice streams. They comprise only ten per cent of ice sheet volume, but carry most of the continent's inland ice to the coast like giant conveyor belts.

When the ice reaches the sea, it floats because it is less dense than water. If the ice is thick and fast-moving enough, it spreads into a permanent floating platform. These ice shelves fringe the continent, some with an area bigger than the UK. When the ice shelves meet warm seawater, they melt, with chunks breaking off.

Climate change is melting Antarctic ice shelves and speeding up its ice streams. The Pine Island Glacier slid into the sea ten per cent faster in the Nineties, while its ice shelf is now melting 50 per cent quicker than the same decade.

Biggest ice shelves



Map of a frozen continent

A grand canyon, spectacular mountain ranges and numerous vast lakes all lay concealed beneath Antarctica's ice...

What's under the ice?

Volcanoes
Western Antarctica contains a rift system similar in length to the East African Rift where Earth's crust is moving apart. Hot rock rises into the gap to form volcanoes. Heat from an under-ice eruption 2,000 years ago may have accelerated Pine Island Glacier (right) – one of Antarctica's biggest and fastest ice streams.

THE STATS ANTARCTICA

AREA 13.8mn km^2

MAX ICE THICKNESS 4,776m

LOWEST POINT SUB SEA LEVEL -2,496m

ICE VOLUME 25.4mn km^3

HIGHEST PEAK 4,892m

COAST LENGTH 45,317km

DID YOU KNOW? *Sea levels would rise 61m (200ft) if all Antarctica's ice melted – enough to submerge the Leaning Tower of Pisa!*

Missions to the final frontier

In *Europa Report*, a 2013 movie, astronauts seek alien life beneath the ice of Jupiter's moon Europa. Real scientists are also seeking new life forms in the cold, dark waters of Antarctica's hidden lakes; their findings could hint at potential extraterrestrial life.

Earlier in 2013, a team of researchers drilled through a kilometre (0.6 miles) of ice to reach Lake Whillans. A baseball bat-sized submarine measured the lake's temperature and salinity, and collected water samples. The team took ten days to reach the lake, dragging their equipment 1,125 kilometres (700 miles) on tractor-pulled sledges. Other previous missions have visited Lake Vostok and Lake Ellsworth.

Scientists use radar mounted on skidoos or aeroplanes to map mountains, canyons and volcanoes hidden deep beneath Antarctica's ice. The radar acts much the same as a bat's sonar, bouncing off obstacles like volcanic ash and bedrock. Knowing the bedrock depth helps us understand how the ice is responding to climate change.

Rift valleys

The eastern and western halves of Antarctica are splitting apart. As they separate, blocks of the Earth's crust drop downwards to create narrow, steep-sided canyons. A rift valley beneath the Ferrigno Ice Stream is channelling warm seawater 100km (62mi) inland, speeding up melting of the ice sheet.

Lakes

Around **400 lakes exist beneath** Antarctica's ice sheets. Among them is Lake Vostok (above), one of Earth's biggest freshwater lakes. The water remains liquid as it's warmed by heat from the Earth's interior, while the ice above the lake acts as a huge insulating blanket.

Mountain ranges

The peaks of the Transantarctic Mountains poke from the ice, but the Gamburtsev Mountain Range is totally buried. Both ranges resulted from rifting, which occurs when sections of Earth's crust pull apart. The crust stretches, warms, forms a dome and eventually breaks apart; the dome's edges then 'bounce' up.

Rivers

Antarctica's hidden lakes may share water via massive flood channels the size of London's Thames. Water pressure increases until the lake flushes like a toilet. In the biggest recorded flood, 6.4km^3 (1.5mi^3) of lake water drained into the Southern Ocean; that's a volume equivalent to Scotland's Loch Ness.

Life

Lakes under Antarctica's ice are among Earth's most extreme environments. Bacteria and single-celled organisms in Lake Whillans survive intense pressures, temperatures of -0.5°C (31°F), eternal darkness and have little connection to the surface. Scientists believe that they survive on rock minerals like sulphur and iron.

The science behind food

Take a look at the chemistry that goes on in the kitchen when we cook our food

Some of the most interesting kitchen chemistry can be observed when baking. Taking four basic ingredients – flour, fat, sugar and eggs – and subtly altering their cooking chemistry can transform them into airy cakes, chewy cookies or flaky pastries.

Leavening, or raising, agents introduce bubbles of air. As the air bubbles are heated, the gas that they contain expands, causing cakes, breads and soufflés to rise. These air bubbles can be made in one of two ways. Chemical raising agents, like baking powder and bicarbonate of soda, react with water to form carbon dioxide gas. This reaction occurs very rapidly and the quantity of raising agent must be carefully adjusted – too much and the bubbles will become large and burst, too little and the density of the cake mixture will prevent any bubble formation at all.

For a slower rise with added flavour, baker's yeast (Saccharomyces cerevisiae) is often used. Yeast is a single-celled organism of the fungi family. At first, the yeast respires aerobically – using oxygen – creating bubbles of carbon dioxide. When the oxygen runs out, the yeast begins to make ethanol by fermentation, much like in brewing beer, but any alcohol formed in the bread dough evaporates in the oven.

Making bubbles is one thing, but getting them to remain intact requires more clever chemistry. Bread is most often made from wheat flour, which contains starch granules surrounded by two important proteins: glutenin and gliadin. When mixed with water and kneaded, the glutenin cross-links to form networks with gliadin, making a new stretchy protein: gluten. Gluten is a 'super-protein', or protein complex, which behaves much like elastic, forming stretchy bridges that hold the starch molecules together. The key to light, fluffy bread lies in creating lots of tiny elastic bubbles; the more the dough is kneaded and stretched, the stronger the gluten network becomes. Eggs act in a similar way to the gluten in flour, providing a protein-binding agent that supports air bubbles and holds cakes together.

Unlike bread, pastries need to be 'short' and crumbly, so bakers try to minimise gluten production, which would lead to a rubbery texture. This is done by first rubbing butter into the flour, coating the starch molecules with a layer of fat, which helps prevent glutenin and gliadin from coming into contact with water.

The texture of baked goods can also be altered using sugar. When sugar is beaten with butter, the sharp edges of the sugar crystals allow tiny air bubbles to form – turning the mixture a pale, creamy yellow colour. These bubbles expand in the same way as the ones created by raising agents, contributing to the light texture of cakes. For the denser consistency of cookies, melted fats and oils are often used because the tendency for bubbles to form next to the sugar crystals is reduced.

Sugar also draws in moisture from the air, which can have a significant effect on the water content of baked goods. Brown sugar attracts more water than white, and finely ground sugars attract more water than the granulated variety. Experimenting with the type of sugar used in a recipe will alter the final moisture content, and therefore the texture.

Chemistry isn't just limited to baking though. Chemical reactions define the taste of meat – which is around 70 per cent water, with the

RECORD BREAKERS
KING OF PUDDINGS

2.1x1.5M

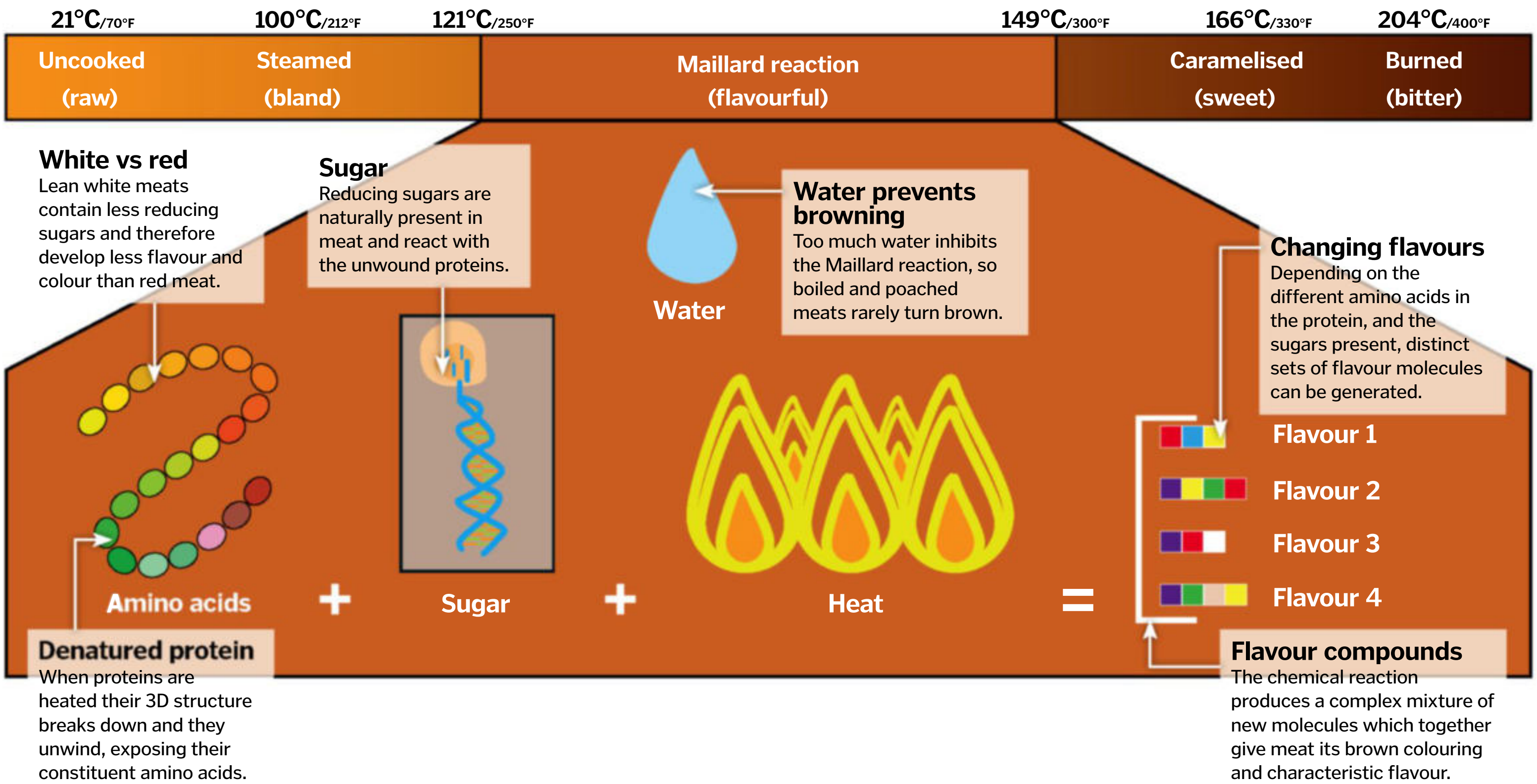
BREAD-'N'-BUTTER BEHEMOTH

Seven chefs, 1,000 slices of bread, 70 apples and 56 eggs were needed to make this mammoth pud 2.1 x 1.5 metres (6.8 x 4.9 feet) in size. It took over 49 hours to prepare.

DID YOU KNOW? The word 'gluten' – the sticky protein that holds breads/cakes together – comes from the Latin for glue

Why cooked meat tastes better than raw

The brown colour of seared meat, toasted bread and roasted coffee beans is down to a chemical process called the Maillard reaction. When foods are heated, amino acids (the building blocks of protein) react with sugars to create hundreds of flavour compounds. Depending on the types and quantities of the various amino acids in the food, different combinations of flavours will be produced, as this diagram shows…



remainder being mostly protein and fat. Depending on the cut, meat contains a variable amount of collagen – a fibrous protein in the skin, tendons and connective tissue. The higher the collagen content, the tougher the meat is.

More expensive cuts and meat from younger animals contain little collagen and can be cooked rapidly. The muscle protein myosin denatures (breaks downs) at low temperatures – ie 50 degrees Celsius (120 degrees Fahrenheit) – and begins to form cross-links, lending some support to the structure of meat. At this stage, water molecules between the proteins start to leak out, but the meat remains juicy and tender. At 60 degrees Celsius (140 degrees Fahrenheit) the red pigment in muscle – myoglobin – denatures to form a hemichrome that gives cooked red meat its brown-grey colour.

Further heating causes the collagen to shrink and contract, forcing water out and turning the meat from juicy and tender to chewy and dry. If the temperature is raised still further – to, say, 70 degrees Celsius (160 degrees Fahrenheit) – the meat continues to toughen, but the collagen itself dissolves to form gelatine. Although the ▶

Cracking the makeup of eggs

The protein content of eggs makes them an extremely versatile chemical tool in the kitchen. Egg white contains a number of globular proteins that normally exist as curled-up, ball-like structures suspended in water. When eggs are cooked, however, the proteins uncurl and then come together to form web-like networks of interconnected protein strands. Water becomes trapped in the web, forming the soft texture of cooked egg white. The longer the proteins are heated, the more links are made in the web, forming an ever-tighter texture, which eventually becomes thick and rubbery.

Whisking egg whites before they are cooked introduces many tiny bubbles. The amino acids on the outside of egg white proteins are hydrophilic (water-loving), while those on the inside are hydrophobic (water-hating).

When the proteins press up against an air bubble, the water-loving amino acids try to move away from the air – uncurling the structure of the protein so that they can 'hide' in the thin film of water that surrounds the bubbles. When heated in this uncurled state, the proteins form links to one another, stabilising the bubbles and helping to support the aerated texture of cakes, meringues, soufflés and many other foods.

> "Marinades use common culinary chemicals to interfere with the bonds between collagen strands"

fibres of meat are more brittle, the gelatine acts as a lubricant, giving slow-cooked meat its soft, 'melt-in-the-mouth' texture.

Heat is not the only way to break down collagen, though, and meat can be physically or chemically tenderised. Marinades use common culinary chemicals to interfere with the bonds between collagen strands – these range from acids like lemon juice to enzymes like bromelain (found in pineapple).

Another great example of kitchen chemistry is the emulsion process. Oil and water don't mix, but to make sauces like mayonnaise and béchamel a cook needs a way to bring them together. When oil and water are combined, the oil floats on top, forming an interface with the water that has high surface tension. In order to break this tension, mechanical shearing can be used – by shaking the container the oil breaks down into smaller and smaller bubbles, which disperse into the water. However, this is only a temporary emulsion (like salad dressing), and after a while the oil and water will separate.

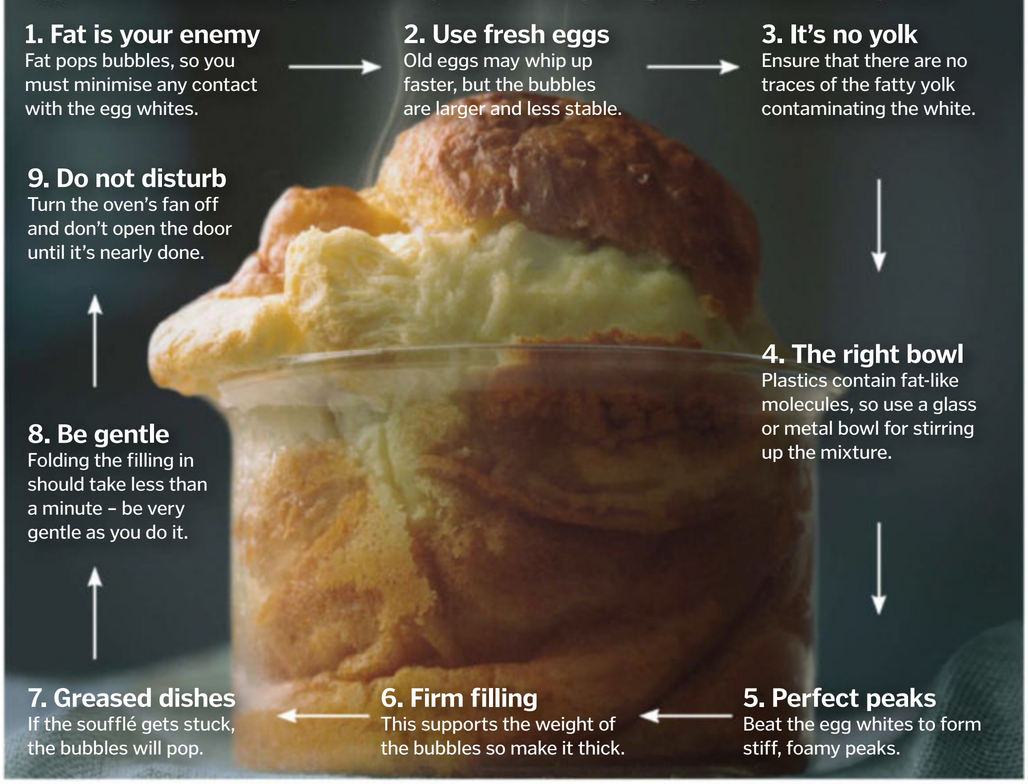
Mayonnaise contains watery egg yolks and fatty butter, which must mix to form a smooth, white paste in a permanent emulsion. Egg yolks contain an emulsifier called lecithin, which dissolves in both fat and water, essentially forming bridges between the yolk and the butter and holding the mayonnaise emulsion in a stable structure. Flour can be used in a similar way in white sauces like béchamel; the fine powder helps to bind the butter to the liquid.

The flavour of food is determined by its combination of volatile components that get into the air and interact with sensory neurons in the nose. Each food may have hundreds of these molecules, but scientists studying flavour combinations have seen that if just one of them matches, foods are likely to go together. The technique is being used to predict many new, unlikely food partners (see 'Strange flavours').

Molecular gastronomy takes the science of cooking to the next level. Looking at food from a purely physical and chemical perspective, a host of chefs and scientists are coming together to identify new flavour combinations and cooking techniques based on science. Using liquid nitrogen, syringes, centrifuges and ultrasound machines, we are starting to reinvent the way we cook. As the founding father of this scientific discipline, Nicholas Kurti, said: "It's a sad reflection on civilisation that while we can and do measure the temperature in the atmosphere of Venus we do not know what goes on inside our soufflés."

The science behind soufflés

Approach soufflé making like a lab experiment and you'll get great results every time



Strange flavour combinations

Some seemingly odd food pairings are surprisingly good, others are just plain disgusting – but why?

Chocolate and salt

Salt actually helps the cells on your tongue to sense the presence of sugar, so it makes chocolate taste even sweeter.

 +  = YUM

Peanut butter and apple

Peanut butter makes up for what an apple lacks in salt and fat, while the apple cuts through the spread's richness and stickiness.

 +  = YUM

Citrus fruit and milk

The acid found in citrus fruit causes milk to separate and curdle – essentially the first step in making cheese. Not appetising.

 +  = YUCK

Chilli powder and fruit

The compound capsaicin present in chilli has two effects: it enhances our sense of smell and also heightens our perception of sweetness.

 +  = YUM

Coffee and olives

We evolved to associate bitterness with poison, so combining too many bitter flavours is often unpleasant.

 +  = YUCK

How many times are refried beans fried?

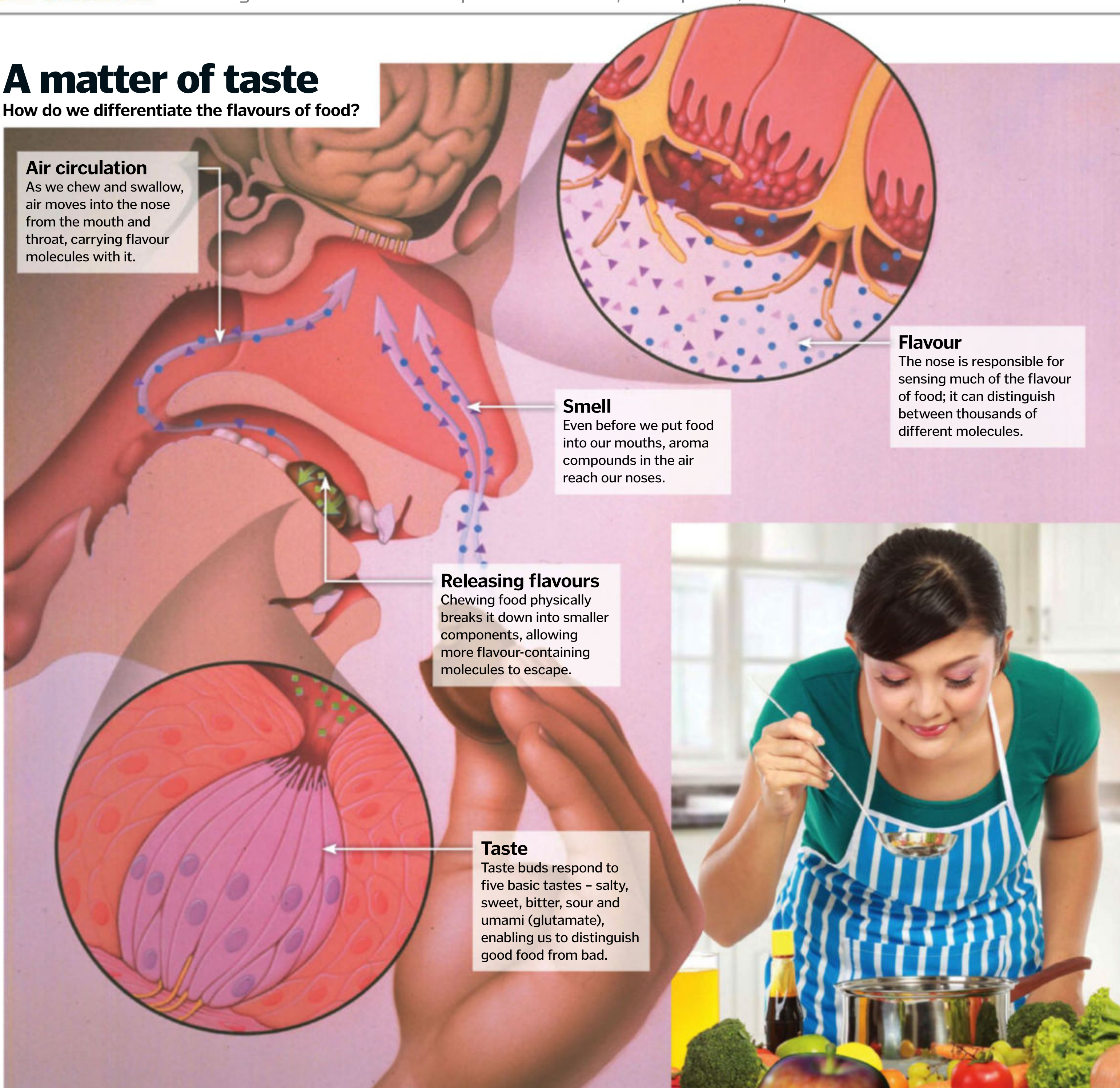
A Once **B** Twice **C** Seven times

Answer:
Refried beans – a traditional Mexican dish of cooked and mashed beans – are actually only fried once. The name 'refried' is the result of a mistranslation. 'Frijoles refritos' actually means 'well-fried beans' but the mistake has stuck.

DID YOU KNOW? *The tongue is not divided into separate areas as often depicted; the five basic tastes are sensed all over*

A matter of taste

How do we differentiate the flavours of food?



Can food make us happy?

People often report cravings for particular foods, and that eating certain meals makes them happy. As a species, we evolved to make eating a pleasant experience, encouraging us to seek out high-calorie food to sustain ourselves when food was scarce.

The human brain has developed reward pathways associated with eating fat and sugar, which release mood-enhancing neurotransmitters, like dopamine and endorphins. Probably the most-studied example is chocolate, which contains phenylethylamine and this affects the body's opioid production.

Comfort food, on the other hand, works more psychologically, and the pleasant feelings that it induces are often linked to sight, smell and taste, which can trigger a sense of nostalgia.

"The low-frequency magnetic fields used don't interact with people or pets, making this tech safe to use"

Wireless electricity

Find out how new technology is set to make power cables a thing of the past

Own an electric toothbrush? Then you already have wireless electricity at home. Toothbrush chargers use inductive coupling to provide power without electrical contacts. When current from the mains runs through a coil of wire in the charger unit, it produces a fluctuating magnetic field which induces a current in a second coil embedded inside the toothbrush. This principle also underlies charging mats which power up phones and cameras at close range.

The catch, however, is that inductive coupling is only effective over a very short range – indeed, stray by just a few millimetres and the magnetic field tails off rapidly.

One solution is to throw resonance into the mix. Resonance is the phenomenon which enables an opera singer to shatter a wineglass with their voice alone. For this to happen, the frequency of the singer's voice has to match the glass's innate resonant frequency – the rate at which the glass naturally vibrates.

To apply this idea to wireless electricity, scientists fine-tune two coils to resonate to the same frequency of magnetic field. This makes transmission across a few metres possible as the second coil amplifies the energy of the first.

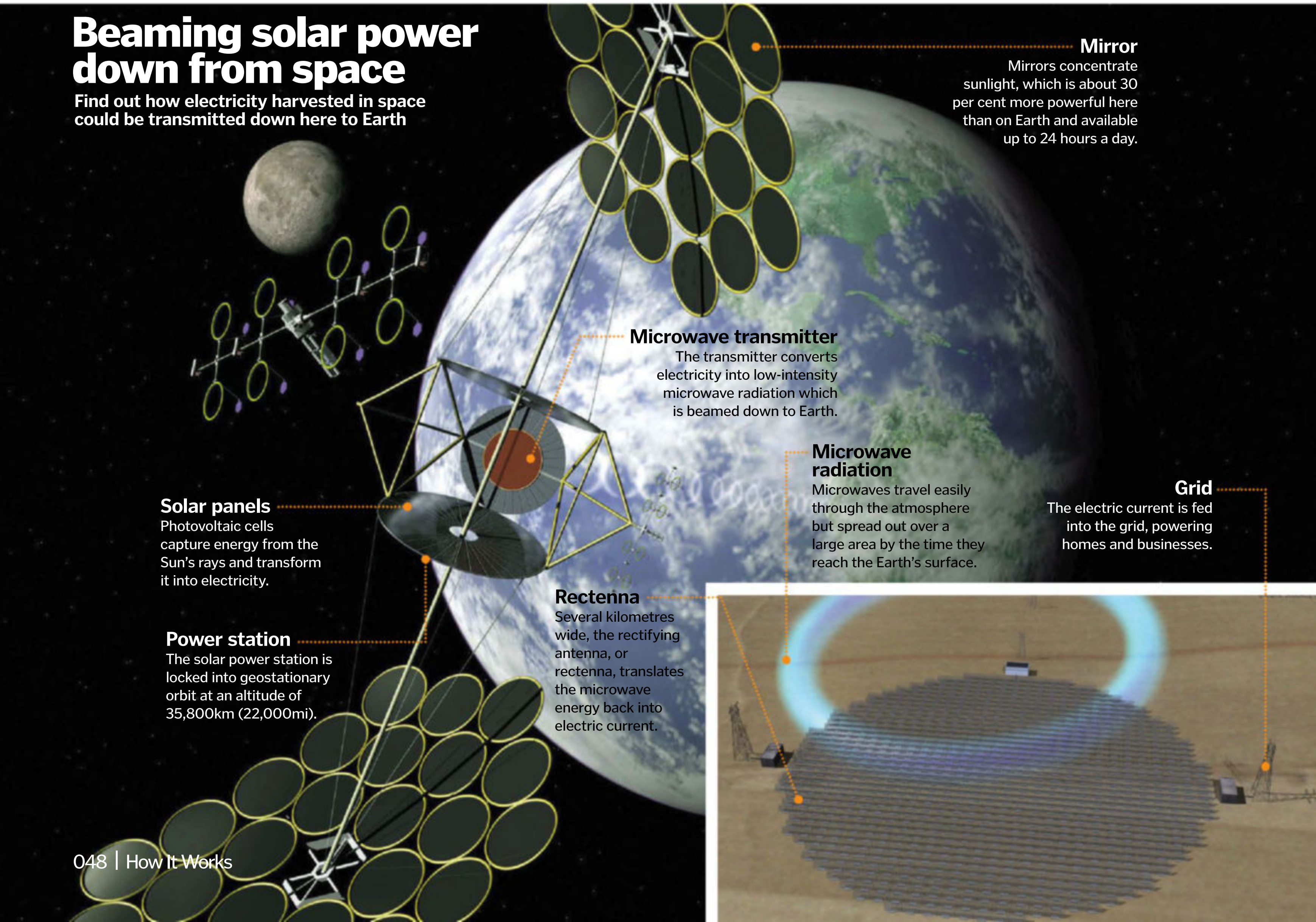
The low-frequency magnetic fields used don't interact with people or pets, making this tech safe to use in a domestic environment.

If you want to beam power over much greater distances though, converting energy into electromagnetic radiation (for example, light or microwaves) is the way to go. Laser-transmitted power has already been used to power unmanned aircraft. First, electricity is converted into a high-powered infrared laser beam; a photovoltaic cell at the other end then turns this back into electrical current.

Microwave-transmitted power follows much the same idea, converting energy into microwaves then back into current with the aid of a rectifying antenna, or rectenna. Although this is more efficient than laser beams it does require much bulkier equipment.

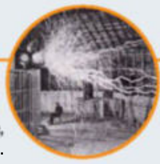
Beaming solar power down from space

Find out how electricity harvested in space could be transmitted down here to Earth



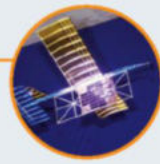
KEY DATES
GOING WIRELESS

1893
Nikola Tesla publicly demonstrates wireless electricity for the first time, though it's quite inefficient.



1968
Peter Glaser suggests wirelessly transmitting solar energy captured in space and space-based solar power is born.

2003
NASA scientists fly a lightweight unmanned aircraft powered solely by a ground-based laser.



2007
Researchers at MIT power a light bulb wirelessly over a distance of 2m (6.6ft), with 40 per cent efficiency.

2009
US company Powermat launches the first commercially successful wireless charging mats.

DID YOU KNOW? *Tesla devised a system that would transmit power wirelessly across the globe, but didn't get funding for it*

Wireless electricity at home

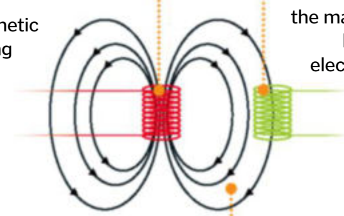
How wireless electricity could rid our homes of those pesky power cables

A common example of wireless electricity in the home is the electric toothbrush which uses inductive coupling technology

Inductive coupling

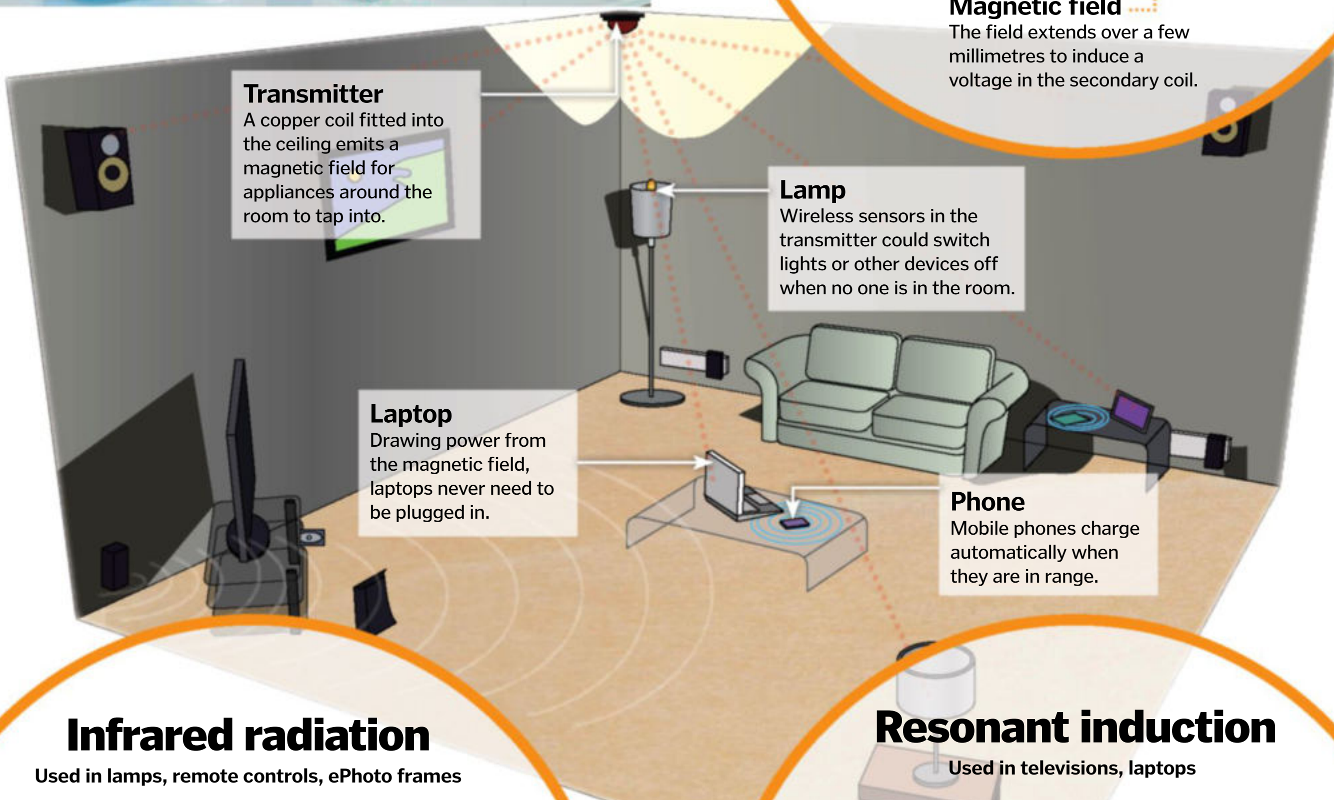
Used in phones, charging mats, toothbrushes

Transmitter coil
Connected to the power socket, this coil generates a magnetic field as alternating current travels through it.



Receiver coil
Inside the appliance, this coil converts the magnetic field back into an electric current.

Magnetic field
The field extends over a few millimetres to induce a voltage in the secondary coil.



Transmitter
A copper coil fitted into the ceiling emits a magnetic field for appliances around the room to tap into.

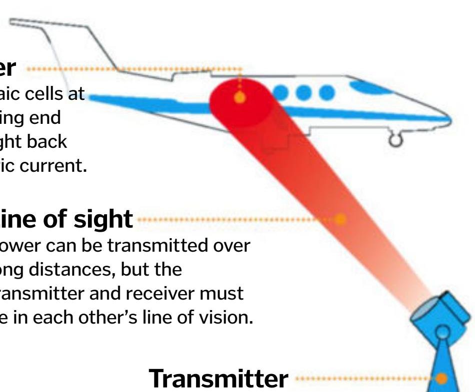
Lamp
Wireless sensors in the transmitter could switch lights or other devices off when no one is in the room.

Laptop
Drawing power from the magnetic field, laptops never need to be plugged in.

Phone
Mobile phones charge automatically when they are in range.

Infrared radiation

Used in lamps, remote controls, ePhoto frames



Receiver
Photovoltaic cells at the receiving end convert light back into electric current.

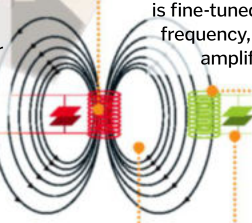
Line of sight
Power can be transmitted over long distances, but the transmitter and receiver must be in each other's line of vision.

Transmitter
Electricity is converted into a concentrated beam of infrared.

Resonant induction

Used in televisions, laptops

Transmitter
Energy oscillates between an electric field in the capacitor and a magnetic field in the coil.



Receiver
The receiving resonator is fine-tuned to the same frequency, allowing it to amplify the energy.

Transmission
This allows for power to be transmitted safely over 2-3m (6-9ft) and even through obstacles.

Current
An electric current is induced in the receiving coil.

© NASA/Mafic

"Leptin – more commonly known as the 'fat hormone' – essentially acts as our internal fuel gauge"

Why do our muscles ache?

Learn what causes stiffness and pain in our muscles for days after exercise

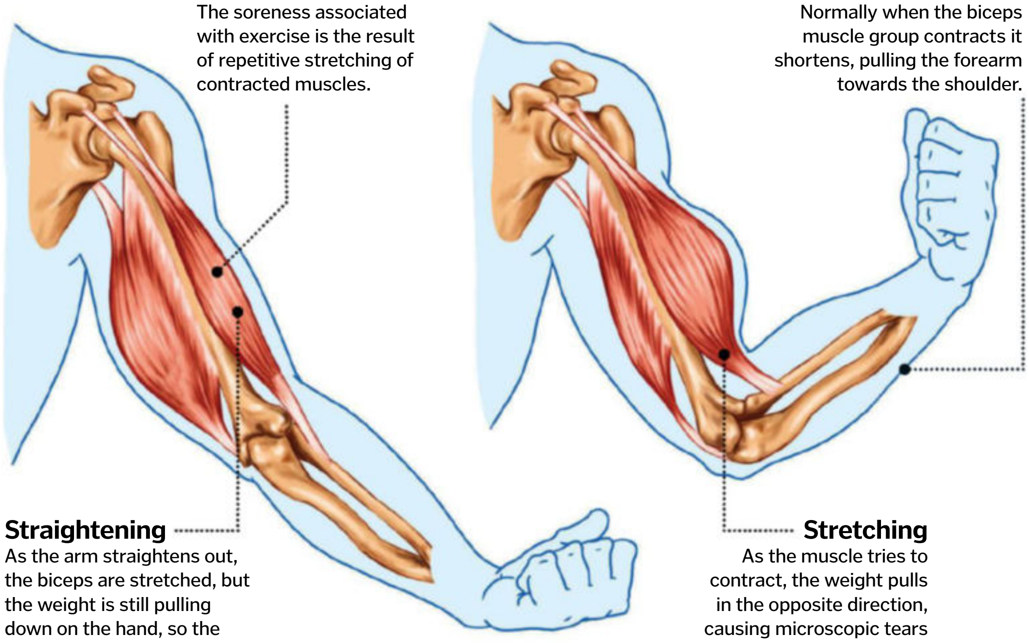
Normally, when our muscles contract they shorten and bulge, much like a bodybuilder's biceps. However, if the muscle happens to be stretched as it contracts it can cause microscopic damage.

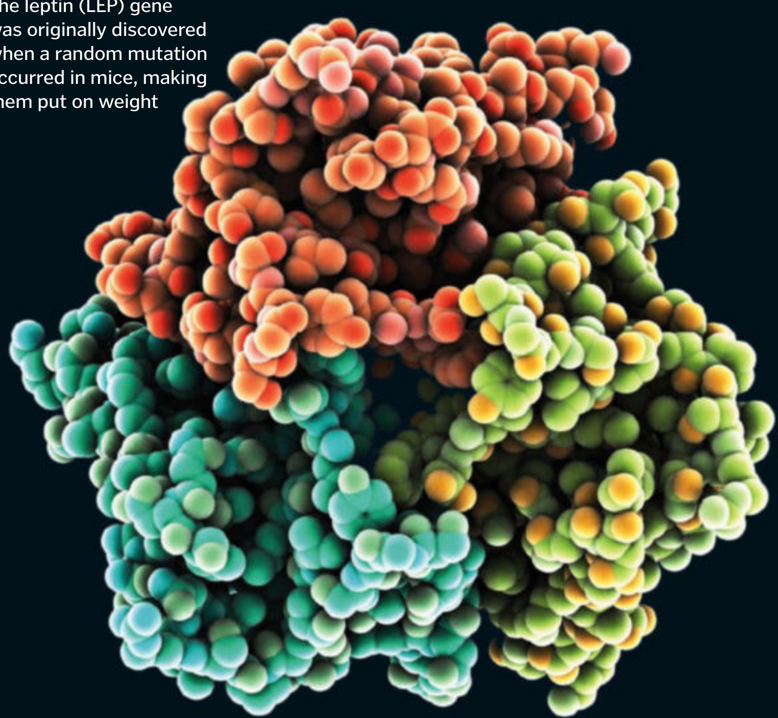
The quadriceps muscle group located on the front of the thigh is involved in extending the knee joint, and usually contracts and shortens to straighten the leg. However, when walking down a steep slope, say, the quadriceps contract to support your body weight as you step forward, but as the knee bends, the muscles are pulled in the opposite direction. This tension results in tiny tears in the muscle and this is the reason that downhill running causes so much delayed-onset pain.

At the microscopic level, a muscle is made up of billions of stacked sarcomeres, containing molecular ratchets that pull against one another to generate mechanical force. If the muscle is taut as it tries to contract, the sarcomeres get pulled out of line, causing microscopic damage. The muscle becomes inflamed and fills with fluid, causing stiffness and activating pain receptors – hence that achy feeling you get after unfamiliar exercise.

Weightlifting and the body

What happens to your biceps when you pump iron?





The leptin (LEP) gene was originally discovered when a random mutation occurred in mice, making them put on weight

The fat hormone

Discover how the body manages to keep track of its energy reserves

In order to know how much food to eat, the human body needs a way of assessing how much energy it currently has in storage. Leptin – more commonly known as the 'fat hormone' – essentially acts as our internal fuel gauge. It is made by fat cells and tells the brain how much fat the body contains, and whether the supplies are increasing or being used up.

Food intake is regulated by a small region of the brain called the hypothalamus, which manages many of our hormones. When fat stores run low and leptin levels drop, the hypothalamus stimulates appetite in an attempt to increase food intake and regain lost energy. When leptin levels are high, appetite is suppressed, reducing food intake and encouraging the body to burn up fuel.

It was originally thought that leptin could be used as a treatment for obesity. However, although it is an important regulator of food intake, our appetite is affected by many other factors, from how full the stomach is to an individual's emotional state or food preferences. For this reason, it's possible to override the leptin message and gain weight even when fat stores are sufficient.

DID YOU KNOW? The pistol shrimp snaps its claws hard enough to produce tiny bubbles that collapse with a flash of light

How bursting bubbles turn sound into light

We shed some light on the unusual phenomenon of sonoluminescence

Sonoluminescence occurs when a tiny bubble focuses energy from sound waves and releases it as light. Producing this effect is surprisingly straightforward: just pour some water into a flask, press some speakers up close and turn the volume up. The changes in pressure as intense sound waves pump through the water are violent enough to break it up, leaving minuscule bubbles of water vapour and gas.

Continuing to fire sound waves at one of these bubbles causes it to expand to ten times its original size before suddenly being crushed. The abrupt collapse focuses the sound energy, compressing the gas inside the bubble. This produces temperatures hotter than the Sun's surface, culminating in an incredibly short flash of blue and ultraviolet light.

Physicists first observed sonoluminescence quite by accident in the 1930s, but it wasn't until 1989 that they were able to study the phenomenon more closely by immobilising a single bubble in water. Even today, it's very difficult to measure what is going on inside the bubbles, meaning that, as yet, not everyone agrees on where the light comes from.

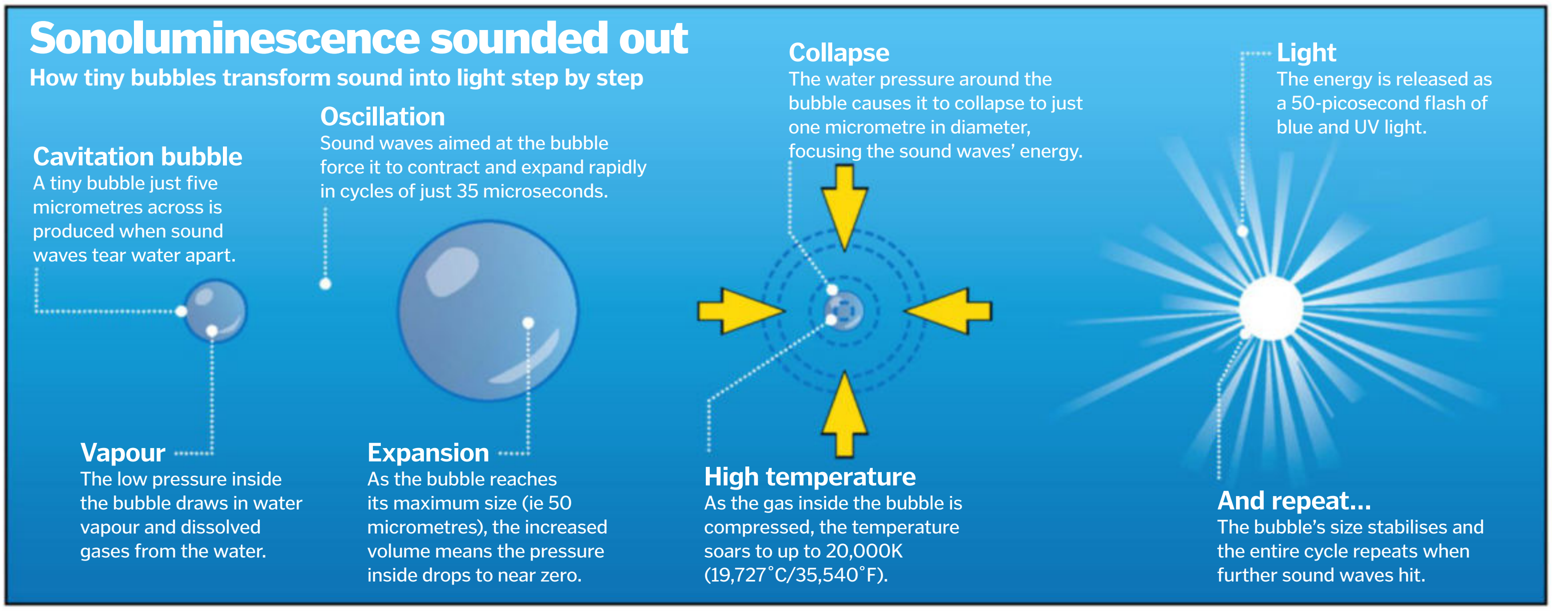
One suggestion is that the high temperature causes noble gases like argon and xenon to incandesce, turning heat into light like red-hot coals. Another idea is that the water molecules themselves are being torn apart and giving off energy as they recombine. Or gas inside the bubble may become a glowing plasma as the extreme heat pulls its atoms apart.

While they are fascinating in their own right, some have suggested sonoluminescent bursts of light could also be used for medical imaging, or to trigger certain chemical reactions very precisely. There are a number of scientists who even believe we could harness the intense energy from sonoluminescence to kick-start nuclear fusion reactions.

A demonstration of acoustic energy being converted into light

Sonoluminescence sounded out

How tiny bubbles transform sound into light step by step



> "By bombarding atomic nuclei with protons or smaller nuclei, scientists have synthesised 20 more elements"

The periodic table

Unlock the wealth of information inside this handy guide to all the elements

The periodic table makes scientists' jobs easier by providing a visual guide to each element's main properties.

An element is a substance made from just one type of atom – carbon, for example. The Big Bang produced a handful of very light elements – mostly hydrogen and helium – which were fused inside stars into many heavier elements, like iron. Add to these another 14 elements produced by radioactive decay and you have our universe's 98 naturally occurring elements.

But it doesn't end there. By bombarding atomic nuclei with protons or smaller nuclei, scientists have synthesised 20 more elements. Produced inside nuclear reactors or particle colliders, these are the heaviest elements in the table, with atomic numbers 99 to 118. Since they are all radioactive, they decay rapidly – some after a few days or weeks, but many in a few fleeting milliseconds. This leaves scientists very little time to assess the properties of new discoveries. While they await official recognition, these elements are assigned temporary names such as Ununoctium.

The periodic table organises all 118 elements in order of increasing atomic number. This long list is then split into rows (called periods) according to how many electron shells each element has. Many of an element's chemical properties are determined by the configuration of electrons sitting in their shells. Elements with just one electron in their outer (valence) shell, for instance, react very easily. Elements in the same column (called a group), meanwhile, have similar electron configurations and therefore share characteristics like reactivity.

A number of other patterns can be found across the entire table. Metallic properties, for example, gradually disappear as you move from the bottom-left corner to the top-right.

Non-metals
With a dull finish, non-metals don't conduct heat or electricity well.

Transition metals
These are hard, with high melting and boiling points.

Poor metals
These malleable metals have fairly low melting and boiling points.

Alkali metals
With just one electron each, alkali metals are very reactive elements.

Metalloids
Despite looking metallic, metalloids are brittle and most act like non-metals.

Alkaline earth metals
Keen to give up two electrons, these metals bond easily.

Halogens
Halogens are just one electron shy of full shells, making them very reactive.

Lanthanoids
These soft metallic elements, known as rare earth metals, are very reactive.

Noble gases
With full outer shells, noble gases rarely react with other elements.

Actinoids
Actinoid radioactive elements exist naturally, while others are manmade.

Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.01																	2 He Helium 4.01
2	3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 15.99	9 F Fluorine 18.99	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminium 26.98	14 Si Silicon 28.08	15 P Phosphorus 30.97	16 S Sulfur 32.05	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.91	36 Kr Krypton 83.79
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niob 92.91	42 Mo Molybdenum 95.96	43 Tc Technetium (97.91)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.91	54 Xe Xenon 131.29
6	55 Cs Caesium 132.91	56 Ba Barium 137.33	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (208.98)	85 At Astatine (209.98)	86 Rn Radon (222.02)
7	87 Fr Francium (223)	88 Ra Radium (226)	89-103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadium (271)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Uut Ununtrium (284)	114 Fl Flerovium (289)	115 Uup Ununpentium (288)	116 Lv Livermorium (292)	117 Uus Ununseptium	118 Uuo Ununoctium (294)

Lanthanoids	57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 157.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.05	71 Lu Lutetium 174.97
Actinoids	89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.02	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

STRANGE BUT TRUE
ELEMENTARY BIOLOGY

What's the most abundant element in your body?

A Hydrogen **B** Carbon **C** Gold

Answer:
Our bodies are mostly water (H_2O), so as a result hydrogen makes up 67 per cent of the average human body's total 7×10^{27} atoms. Because hydrogen is very light, however, it only accounts for around ten per cent of our mass.

DID YOU KNOW? *The element mercury owes its unusual chemical symbol – Hg – to hydrargyrum, Latin for 'liquid silver'*

Building blocks

Take a glance at the key information displayed in each element on the table

Atomic number
The number of protons and electrons in the element.

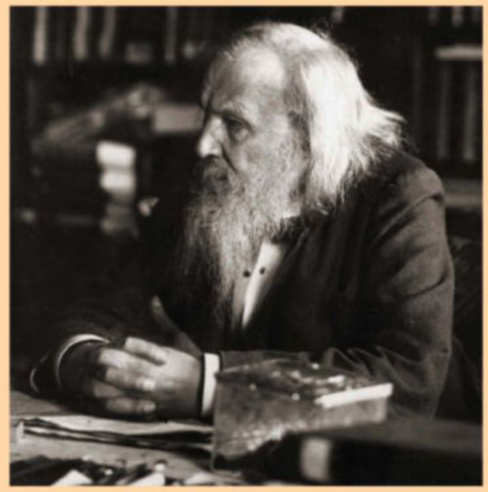
Chemical symbol
One or two letters used as a short form to represent the element.

Title
The element's full name for those who don't know their symbols.

Atomic mass
The mass of an atom, which is measured in atomic mass units. This also takes into account the atom's neutrons.

Mendeleev's table

Russian chemist Dmitri Mendeleev published one of the earliest versions of the periodic table in 1869, laying the foundations for the table we know today. Ordering over 60 known elements according to their atomic weight, he noticed that elements with similar properties occurred at regular intervals – in other words, periodically. Grouping elements to reflect these trends, three gaps remained. Mendeleev concluded that undiscovered elements must fill these gaps, deducing some of their properties from their position in the table. The discovery of gallium, scandium and germanium soon after confirmed Mendeleev's predictions, and scientists worldwide adopted his table. Over the years, Mendeleev's table has been updated to include previously unknown groups of elements such as the noble gases, and re-ordered by atomic number to create a more accurate arrangement.

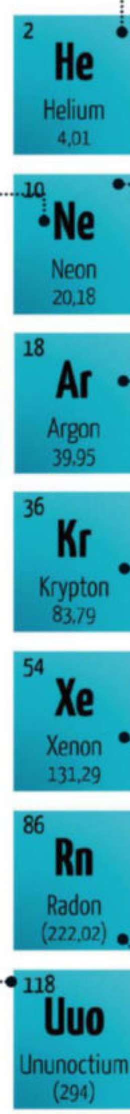


Grouping the elements

The table's 18 groups, displayed in columns, have the most in common due to their shared electron configurations. Trends also exist within groups. For example, as you move from top to bottom, you need more energy to tear an electron away from its atom (ie ionisation energy increases).

Within periods, the table's horizontal rows, similar patterns exist but they are generally weaker. Periods owe their shared characteristics to having the same number of electron shells. Generally, as you move from left to right, elements become more reactive and their size (atomic radius) increases.

Group 18 (noble gases)



Helium
Outer shell electrons: **2 (out of 2)**
Protons in nucleus: **2**
How reactive relative to other elements:
Very unreactive

Neon
Outer shell electrons: **8 (out of 8)**
Protons in nucleus: **10**
How reactive relative to other elements:
Very unreactive

Argon
Outer shell electrons: **8 (out of 8)**
Protons in nucleus: **18**
How reactive relative to other elements:
Very unreactive

Krypton
Outer shell electrons: **8 (out of 8)**
Protons in nucleus: **36**
How reactive relative to other elements:
Very unreactive

Xenon
Outer shell electrons: **8 (out of 8)**
Protons in nucleus: **54**
How reactive relative to other elements:
Very unreactive

Radon
Outer shell electrons: **8 (out of 8)**
Protons in nucleus: **86**
How reactive relative to other elements:
Very unreactive

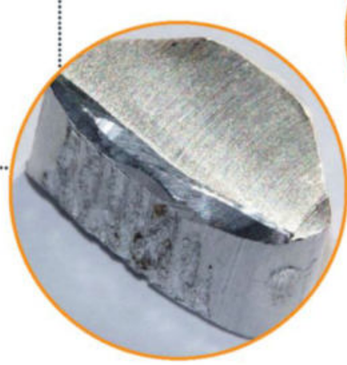
Ununoctium
Outer shell electrons: **8 (out of 8)**
Protons in nucleus: **118**
How reactive relative to other elements:
Very unreactive

Period 3

Sodium
Outer shell electrons: **1**
Protons in nucleus: **11**
How reactive relative to other elements:
Extremely reactive

Magnesium
Outer shell electrons: **2**
Protons in nucleus: **12**
How reactive relative to other elements:
Highly reactive

Aluminium
Outer shell electrons: **3**
Protons in nucleus: **13**
How reactive relative to other elements:
Reactive

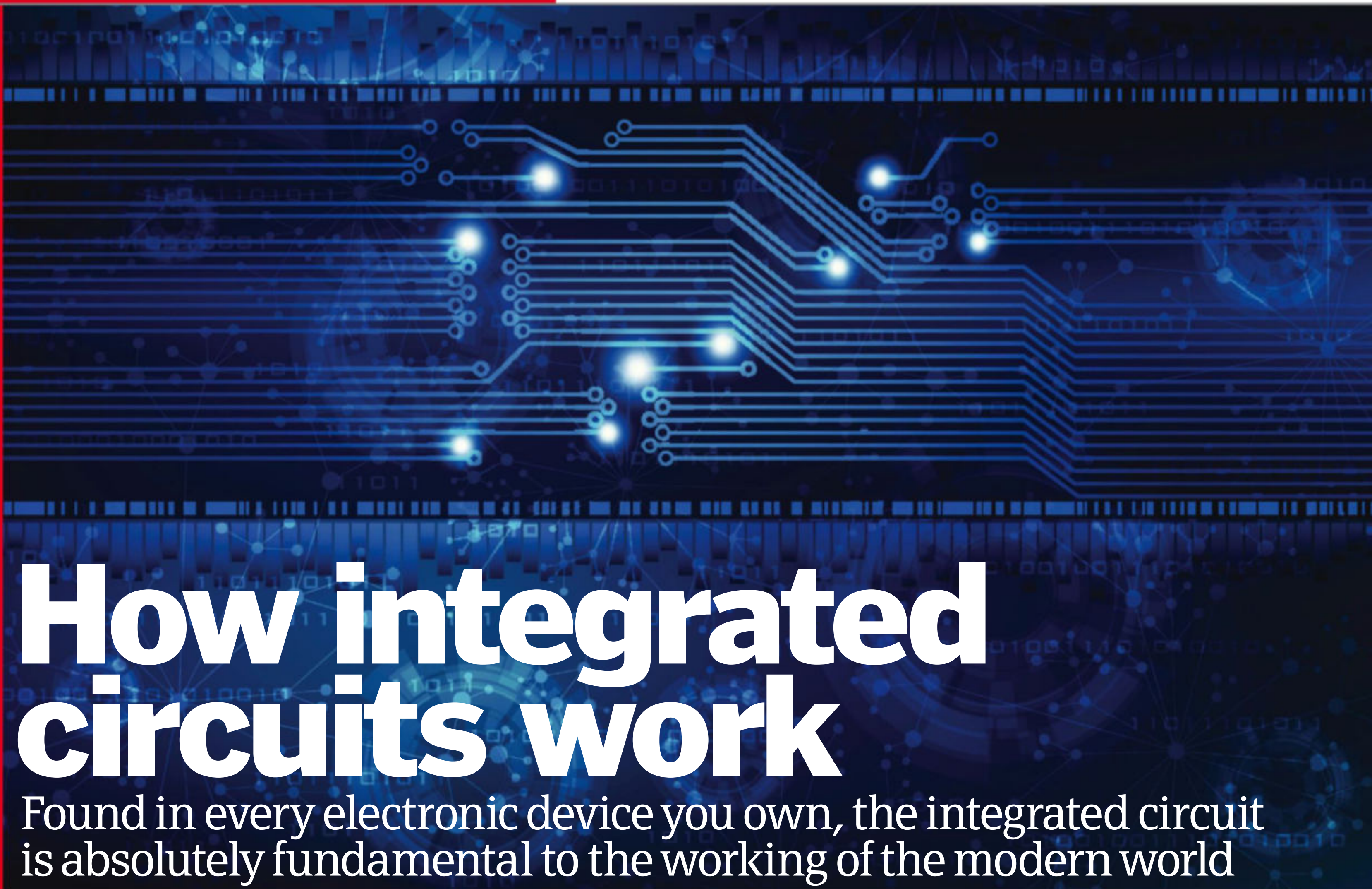


Silicon
Outer shell electrons: **4**
Protons in nucleus: **14**
How reactive relative to other elements:
Relatively unreactive

Phosphorus
Outer shell electrons: **5**
Protons in nucleus: **15**
How reactive relative to other elements:
Reactive

Chlorine
Outer shell electrons: **7**
Protons in nucleus: **17**
How reactive relative to other elements:
Highly reactive

Sulphur
Outer shell electrons: **6**
Protons in nucleus: **16**
How reactive relative to other elements:
Reactive



How integrated circuits work

Found in every electronic device you own, the integrated circuit is absolutely fundamental to the working of the modern world

When the greatest inventions of the 20th century are weighed up for their merits there are few people who think of the integrated circuit. Sure, they often name some of the devices which it has enabled – which isn't difficult as they are numerous – but rarely do we celebrate the bundle of transistors that was first crudely assembled in 1958.

And, you know what, in many ways that is totally understandable. The integrated circuit is by its very small, or – in a more modern and accurate context – nanoscale, nature largely unimpressive. It's essentially a handful of metal and semiconductor components strapped together to perform invisible functions. But it is through these circuits that all modern electrical devices operate, with everything from personal computers through to smartphones and televisions relying on them to perform all number of essential processes.

An integrated circuit is an assembly of miniaturised active and passive devices; active examples include transistors and diodes, while passive examples include capacitors and resistors. Together they are built up on a thin substrate of semiconductor material such as silicon (which is where the USA's chip-making region Silicon Valley gets its name).

Combined, these structures create a computer chip, which typically range from a few millimetres up to a few centimetres (eg CPUs) in size. These chips protect their numerous internal integrated circuits with plastic shells and are combined to create the super-powerful electronic devices many of us couldn't live without today.

In this feature **How It Works** takes a closer look at the science, manufacturing processes and history of the tiny integrated circuit, charting its development over 60-plus years and contemplating what integrated circuits may have in store for the future.

Integrated circuits

Follow some of the key milestones in the development of the integrated circuit

1947

The point contact transistor is discovered at Bell Labs. The p-n junction transistor is created the following year.

1952

British electronics engineer Geoffrey Dummer (right) conceives of the integrated circuit. He builds a prototype and presents it at a conference in Washington DC, USA.

1958

The first proper integrated circuit is built by Jack Kilby at Texas Instruments. It features a transistor, several resistors and a capacitor.

5 TOP FACTS
CIRCUIT TRIVIA

It starts in Texas...
1 The first work on building an integrated circuit was undertaken at world-leading semiconductor manufacturer Texas Instruments by new recruit Jack Kilby in 1958.

Circuits take off
2 Following the invention and later patenting of the integrated circuit in 1959, the US Air Force became the first organisation to place orders for the new technology.

Integrated rival
3 Robert Norton Noyce also invented his own integrated circuit in 1959, which went on to be patented and produced in bulk. It was superior to Kilby's original.

IEEE milestone
4 The Institute of Electrical and Electronics Engineers (IEEE) considered the invention of the semiconductor integrated circuit one of their prestigious 'IEEE Milestones' in 2009.

A Nobel end
5 Co-inventor of the integrated circuit Jack Kilby was awarded the Nobel Prize in Physics in 2000 for his pioneering contribution to circuits. He died five years later aged 81.

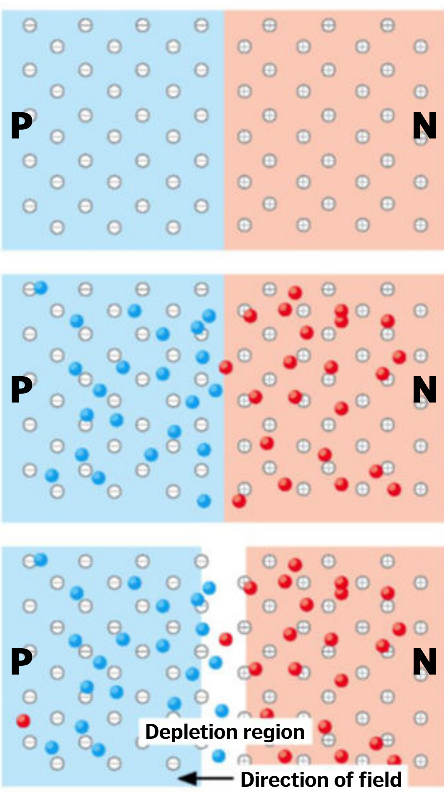
Silicon is the second-most abundant element on Earth, beaten only by oxygen

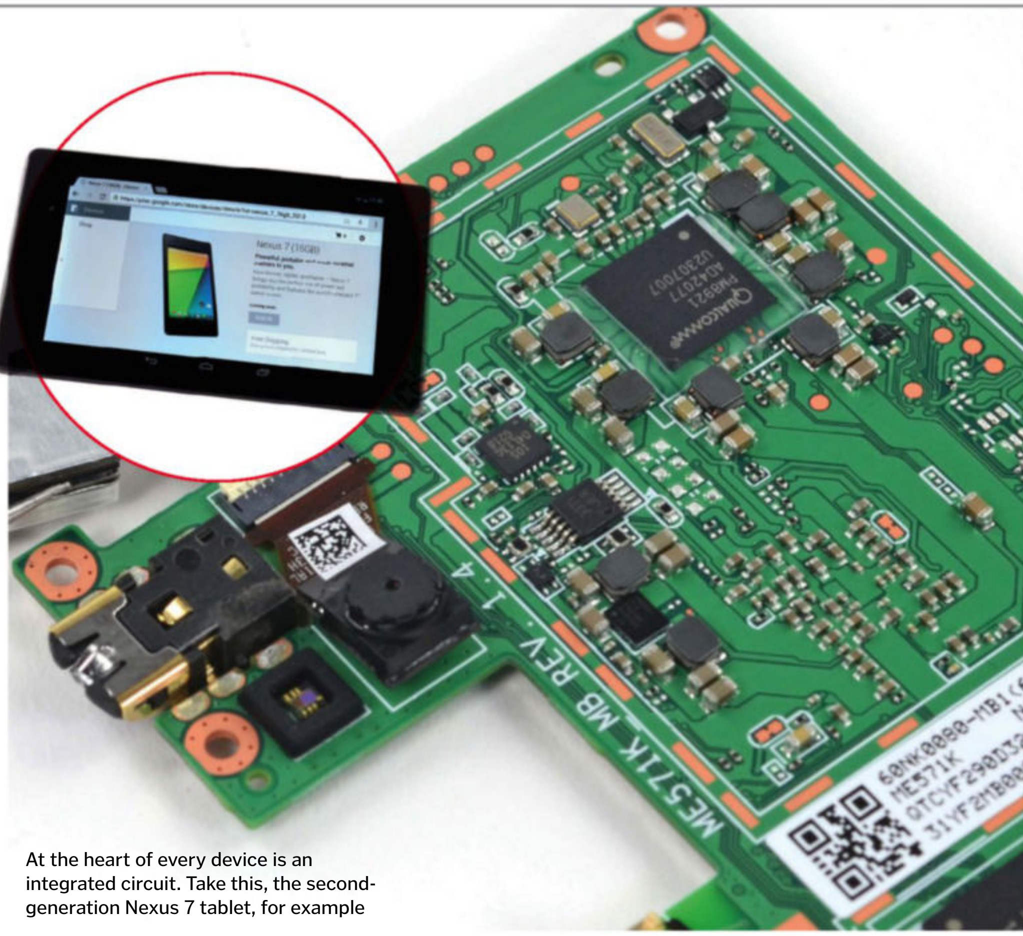
Understanding p-n junctions

A p-n junction is part of an integrated circuit that acts as a barrier to conduction between two types of semiconductor material. In essence, a p-n junction is therefore a type of diode, allowing current to flow or not flow in a specific direction.

When an n-type semiconductor material such as cadmium arsenide (Cd_3P_2), which has a high electron count/mobility, is joined to a p-type semiconductor material such as copper sulphide (Cu_2S), which has a high electron hole concentration, electrons filter from the n-type side to the p-type side and some holes to diffuse vice versa. This switching action leaves two areas of positively and negatively charged ion cores where the two semiconductors meet, between which an electric field forms – known as the depletion zone/region. As the electric field has a direction, a voltage is generated, either with a forward or reverse bias.

Consequently, p-n junctions can be used to create transistors – electrical switches – from which all digital circuits are built from.





At the heart of every device is an integrated circuit. Take this, the second-generation Nexus 7 tablet, for example

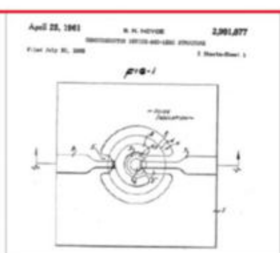
Analogue vs digital

There are two basic types of integrated circuit: analogue and digital. Analogue, or linear, circuits are the most basic and are used typically in electronic devices that collect or send signals such as microphones. In this example, an analogue circuit is used to modify the incoming microphone signal, such as amplifying it, improving the audio projection.

In contrast, digital circuits – which are common in electronic devices like computers and smartphones – are more complicated. These integrated circuits operate in a binary on/off way, which according to Boolean algebra (logic rules) allow for a series of functions.

It is by combining multiple digital integrated circuits together that modern microprocessors are built, with the processors' clock frequency determining the speed various functions are performed.

1961
The US Patent Office awards American electrical engineer Robert Noyce the first patent for an integrated circuit.

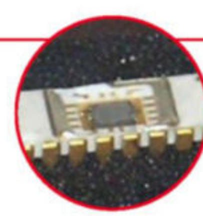


1963
The first commercial, mass-produced integrated circuits begin to be sold by Silicon Valley founder Fairchild Semiconductor.

FAIRCHILD SEMICONDUCTOR®

1965
Electrical engineer Gordon Moore predicts that the integrated circuit density-to-dollar ratio will double every 18 months.

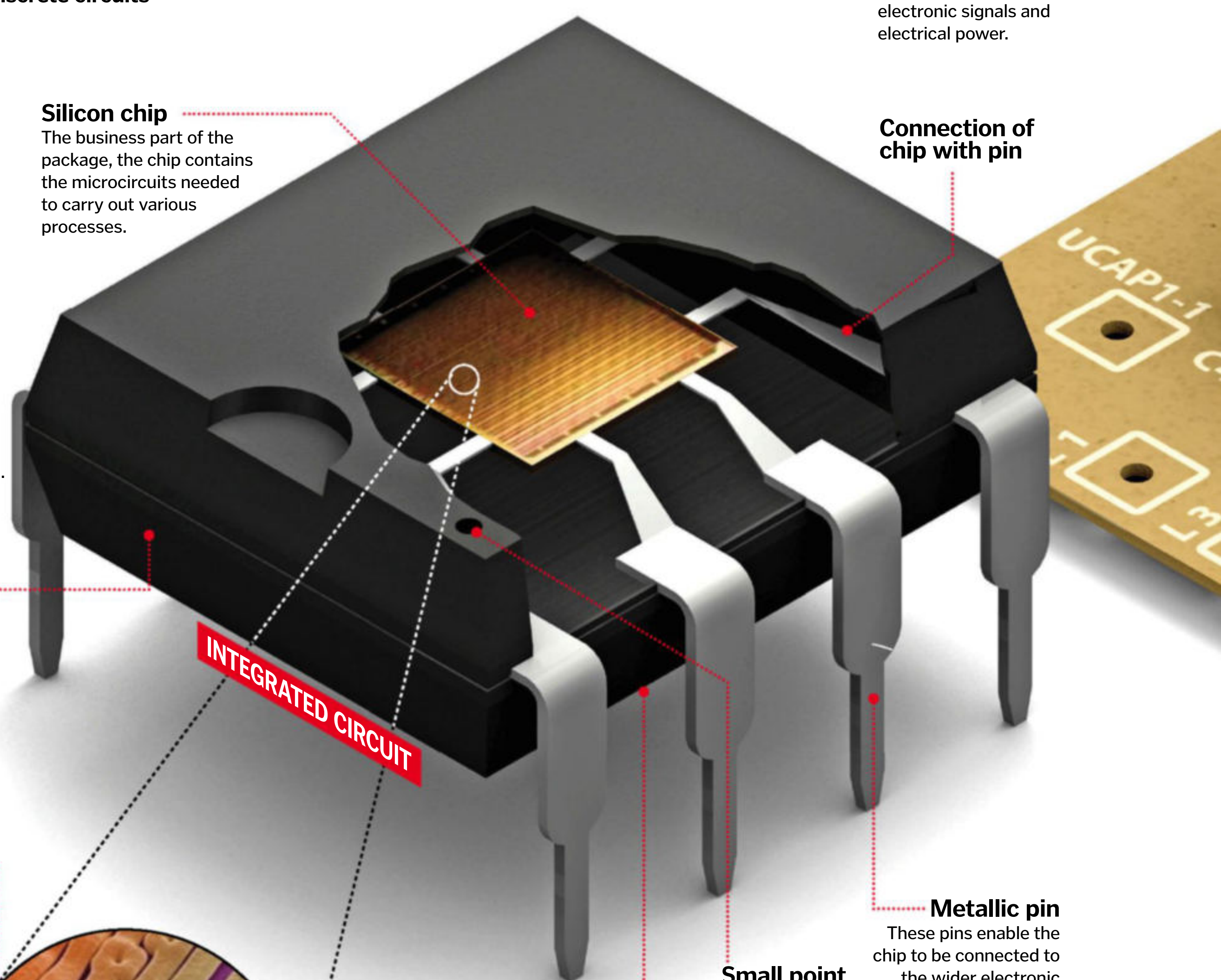
1971
After being founded in 1968, Intel goes on to produce the Intel 4004, the world's first microprocessor. The processor runs at 108KHz and has 2,300 transistors.



“Microcircuits determine the movement of currents within the microprocessor”

Circuitry up close

We take a look at the nanoscale tech that distinguishes integrated and discrete circuits



Transistor
A semiconductor device capable of amplifying and switching electronic signals and electrical power.

Silicon chip
The business part of the package, the chip contains the microcircuits needed to carry out various processes.

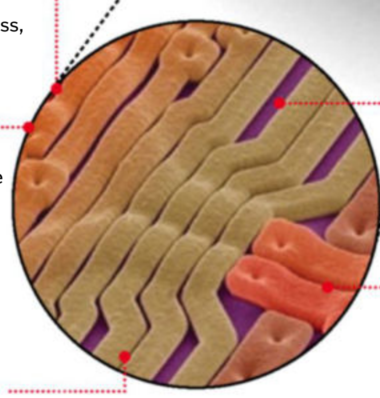
Connection of chip with pin

All in one
Generally chips are encased in the substrate and protection structures, which connect the chip to the rest of the electronic components.

What are they used for?
The integrated circuit has a wide variety of functions: oscillators, amplifiers, flash memories are just a few examples of its many applications.

Plastic cover

Under the microscope
In order to discover the chip structure, it should be viewed with a powerful magnifying glass, or directly under a microscope.



Microcircuits
Made up of thousands of tracks, microcircuits determine the movement of currents within the microprocessor.

Tracks

Substrate
Works as a base and an insulator of the microprocessor’s circuits.

Connection points
These indicate where the circuits are connected to the components located on the opposite side of the substrate via tracks.

Small point

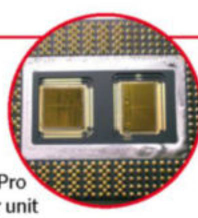
Metallic pin
These pins enable the chip to be connected to the wider electronic system (such as a circuit board).

Integrated circuit
The electronic integrated circuit, which replaced the discrete one, contains all components in one piece and it is manufactured and connected all in the same process.

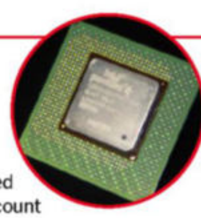
1981
Very large-scale integration processes are introduced with circuits exceeding 100,000 transistors.

1989
Intel releases its hugely popular i486 microprocessor unit, which has a commercial record of 1.2 million transistors.

1995
Intel’s Pentium Pro microprocessor unit launches packed with 5.5 million transistors.



2000
Intel takes speed and transistor count to a whole new level, with its Intel Pentium 4 CPU boasting 42 million transistors and a speed of 1.5GHz.

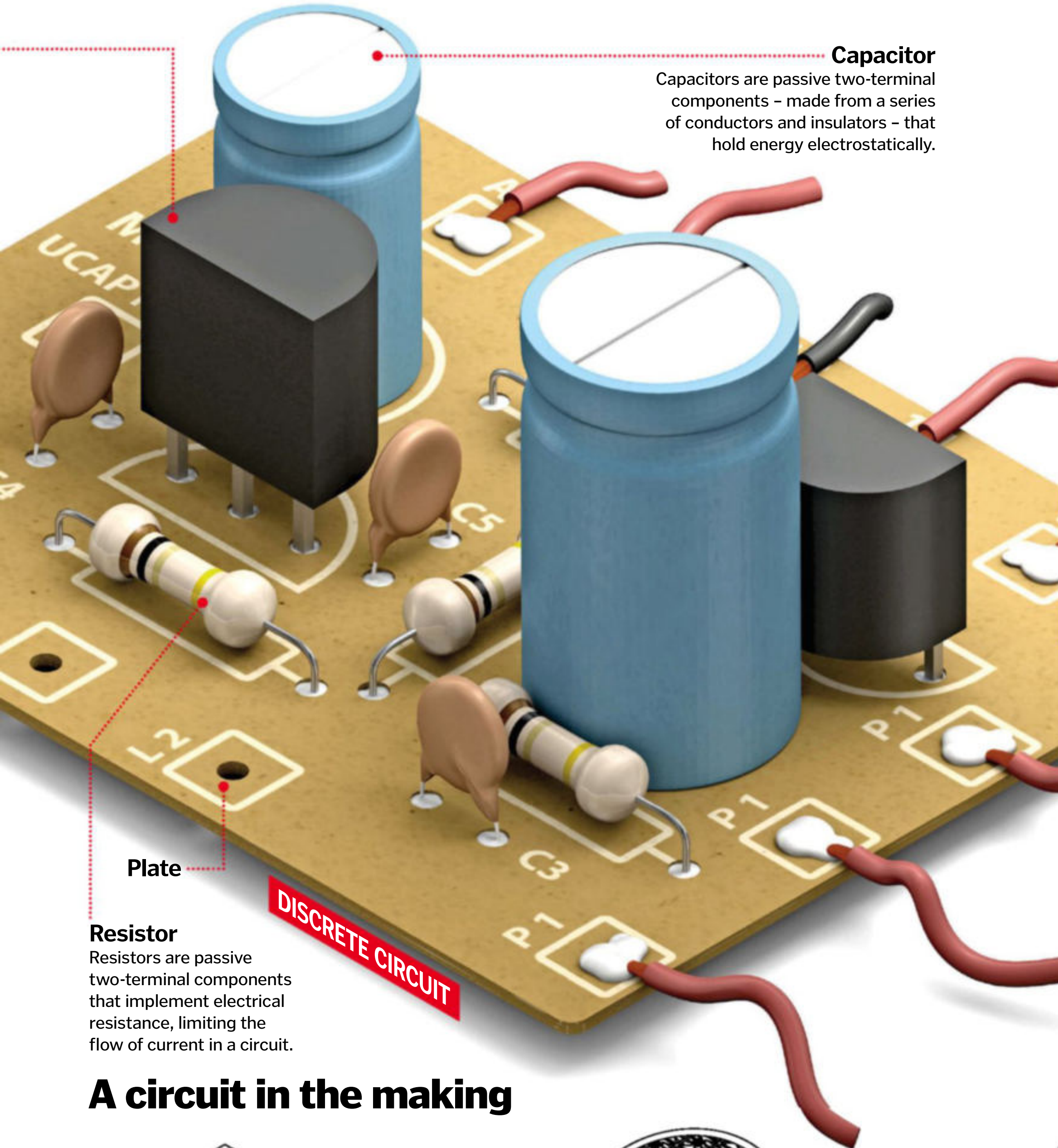


2.6bn

MOST CPU TRANSISTORS

The Intel ten-core Xeon Westmere-EX boasted the highest transistor count in a commercially available CPU as of the end of 2012, clocking in with a whopping 2.6 billion transistors!

DID YOU KNOW? 3D integrated circuits are now starting to be built with vertical and horizontal layers



Capacitor
Capacitors are passive two-terminal components – made from a series of conductors and insulators – that hold energy electrostatically.

Plate

Resistor
Resistors are passive two-terminal components that implement electrical resistance, limiting the flow of current in a circuit.

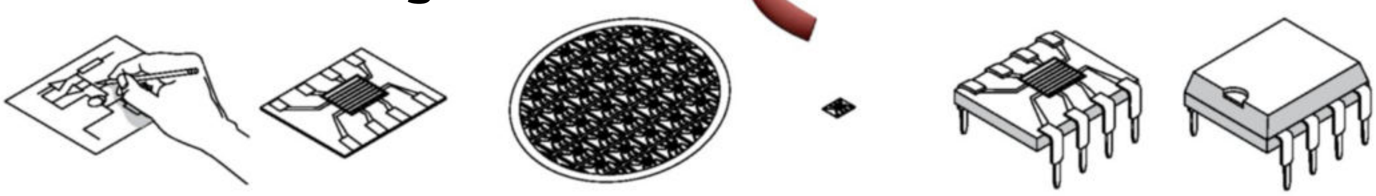
Discrete circuit
Discrete circuits are those where the components are encapsulated in themselves and welded onto a substrate.

What came before the integrated circuit?

The famous Electronic Numerical Integrator and Computer (ENIAC) is the perfect example of the period before the integrated circuit.

Built in the USA in 1946 to calculate the trajectories of projectiles, this machine of 27 tons could solve 5,000 additions in one second, thanks to its nearly 18,000 vacuum tubes. Today, a microchip that fits on the tip of your finger far exceeds this ability.

A circuit in the making



1. Draw circuit
Integrated circuit design is drawn onto paper.

2. Photolithography
With a photolithography process the design is copied onto a silicon wafer.

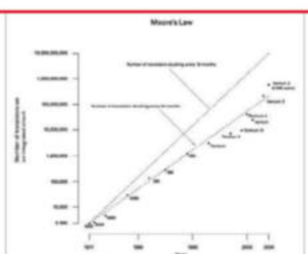
3. Add circuit
The circuit is transferred to a wafer. There are multiple circuits per wafer.

4. Trim excess
Any empty sections on the wafer are cut.

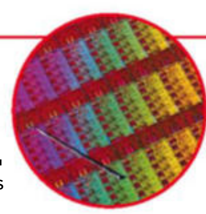
5. Terminals
The circuit terminals are welded on.

6. Plastic shell
Finally the protective plastic casing is mounted.

2005
Moore's Law reaches its 40th anniversary as processors emerge that contain hundreds of millions of transistors.



2011
Transistors start to be manufactured in super-tiny 22-nanometre processes en masse.



2012
Intel begins mass-producing 3D transistors with its 22-nanometre process, naming them Tri-Gate transistors.

2013
Intel builds a new fabrication facility in Arizona, USA, which is to make chips on a next-gen 14-nanometre process.

"Gravity pulls the water through the sand and small particulates become trapped in the tiny grains"

Inside a swimming pool

Take the plunge to see the hidden technology that keeps pools safe and clean

At first glance, a swimming pool might just look like a huge basin filled with water, but hidden beneath the surface is a surprising amount of technology.

The water is constantly circulated through a filtration system, passing out of the main pool through two or more drains at the bottom as well as 'skimmer' drains located around the sides. The main drains collect any debris that sinks to the bottom of the pool, while the skimmer drains take in small amounts of surface water in order to sift out any floating contamination, like hair, bugs and leaves.

The water is drawn through the system by an electric motor, which drives a pump. As the water flows towards the pump a sieve removes any large debris. The water then enters the filtration system, which contains high-grade sand in a vertical column. Gravity pulls the water through the sand and small particulates become trapped in the tiny grains, before the cleaned water passes back out into the pool.

The pump system generates powerful suction, which could create dangerous vortices in the water; the main drains have anti-vortex covers to prevent this from occurring. The use of multiple drainage points also minimises the risk of people becoming trapped by suction; if one drain becomes blocked, the pump draws water from the others, decreasing the suction and usually dislodging the blockage.

Some form of heater is often included in the pump system as well to warm the water as it passes through; a thermostat switches the heater on and off as required to maintain the temperature at a comfortable level.

Focus on chlorine

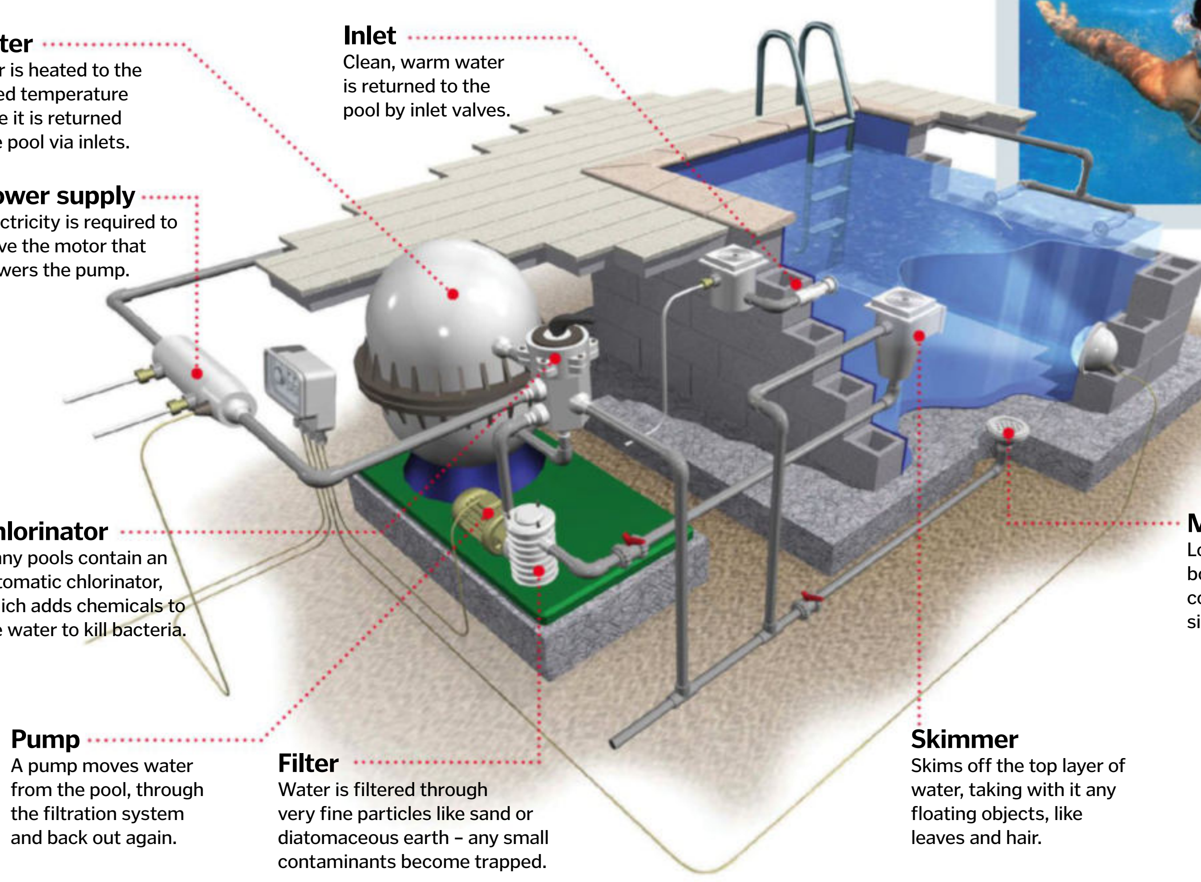
The majority of the technology in a swimming pool is designed to keep it free of debris and to maintain water temperature. But microscopic organisms thrive in warm, still water, so to keep the pool safe, chemical sterilisation is often used.

Chlorine – either in the form of calcium hypochlorite or sodium hypochlorite – is added as a disinfectant. It reacts with water to form hypochlorous acid, which interferes with bacterial cell walls, DNA and enzymes.

Hypochlorous acid breaks down when exposed to UV light though, which is particularly problematic in outdoor swimming pools. Often a stabilising agent is added to keep the chlorine in a usable form for longer. Hypochlorous acid also reacts with ammonia (found in urine) to form compounds called chloramines, which smell bad and can irritate the eyes. A careful balance of chlorine and stabilisers must be maintained to keep the pool safe yet comfortable to swim in.

Beneath the surface...

The underground plumbing of a swimming pool filtration system



RECORD BREAKERS
COLOSSAL CORNBALL

1,500kg

WORLD'S LARGEST CORNBALL

Measuring a staggering 7.5 metres (24.5 feet) in circumference, and weighing in at over 1,500 kilograms (3,400 pounds), the world's biggest popcorn ball was made in Illinois, USA, in 2006.

DID YOU KNOW? *Each day the UK produces enough rubbish to fill the whole of Trafalgar Square and bury Nelson's Column!*

Solar-powered rubbish bins

They crush our litter, send an email when they are nearly full and are powered entirely by the Sun – but what tech makes these trash cans so sophisticated?

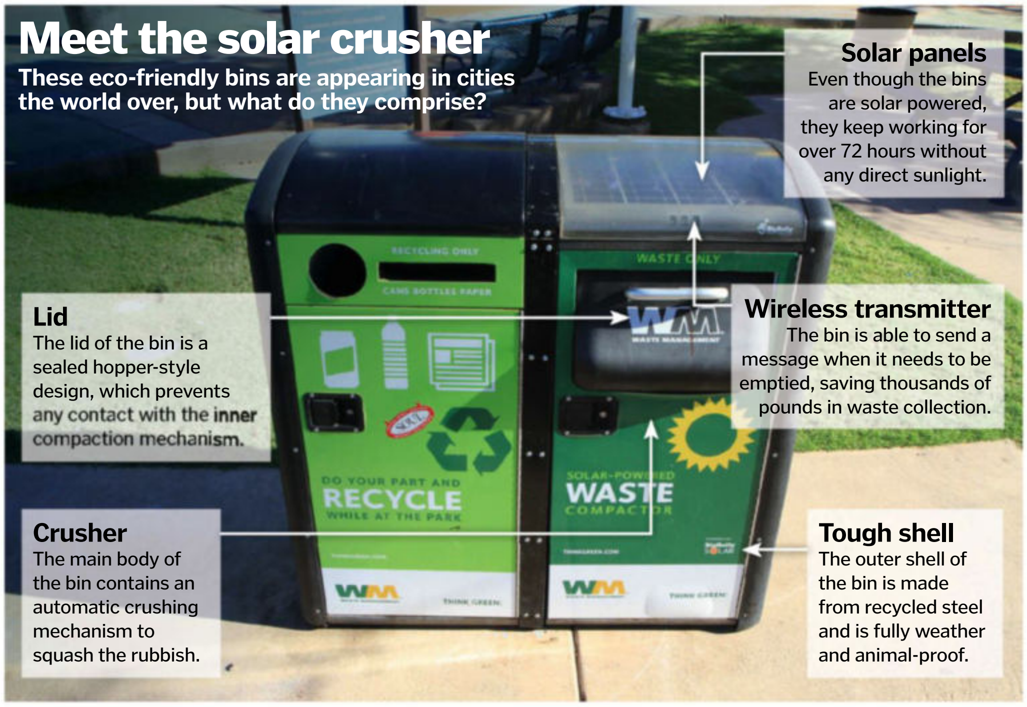
Solar-powered bins contain a sensor to detect when they are full. When litter reaches the level of the sensor, an internal compaction mechanism is activated, crushing the rubbish to make more space. The bins can therefore hold up to eight times more refuse than traditional trash cans, with a capacity of around 800 litres (180 gallons).

The compaction mechanism runs on a standard 12-volt battery and does not use hydraulic fluid, so requires very little power. This enables the bins to be used in areas that receive little direct sunlight; in fact, they can even work in the shade – most need just eight hours of sunlight a month to power the compactor and internal electrical components.

Many solar-powered bins also include a sensor connected to a wireless cellular data transmitter, which sends a signal to the local waste disposal company when the bin has been filled to 85 per cent capacity. This makes the waste collection process much more efficient.

Meet the solar crusher

These eco-friendly bins are appearing in cities the world over, but what do they comprise?



Solar panels Even though the bins are solar powered, they keep working for over 72 hours without any direct sunlight.

Lid The lid of the bin is a sealed hopper-style design, which prevents any contact with the inner compaction mechanism.

Wireless transmitter The bin is able to send a message when it needs to be emptied, saving thousands of pounds in waste collection.

Crusher The main body of the bin contains an automatic crushing mechanism to squash the rubbish.

Tough shell The outer shell of the bin is made from recycled steel and is fully weather and animal-proof.

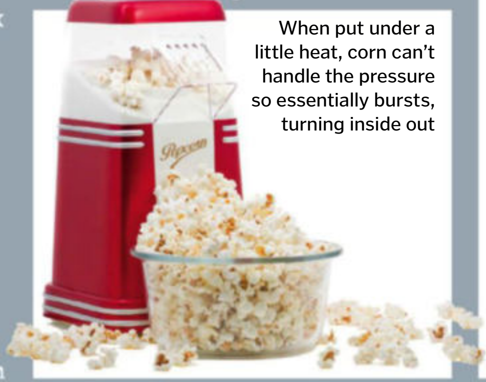
Popcorn machines

Popcorn makers rapidly turn hard corn kernels into fluffy popcorn, but how do they do it?

Dried corn kernels contain about 12-15 per cent water, which turns to vapour when heated. As the steam expands, pressure builds up inside the tough outer shell of the kernel until eventually the corn bursts. The starch granules inside the kernel become gelatinous when heated and expand outwards to form a network of jelly-like bubbles. As they cool, they solidify to leave the puffy, white snack we are all familiar with.

Traditionally, popcorn makers use hot oil to convert the internal moisture of the kernels to steam, but hot air can also be used. Within the main chamber of a popcorn maker there is an electric heating element, which warms the oil or air. The kernels are placed inside the chamber and mixed continually by a fan or rotating blade to prevent them from burning before they reach the temperature required to pop.

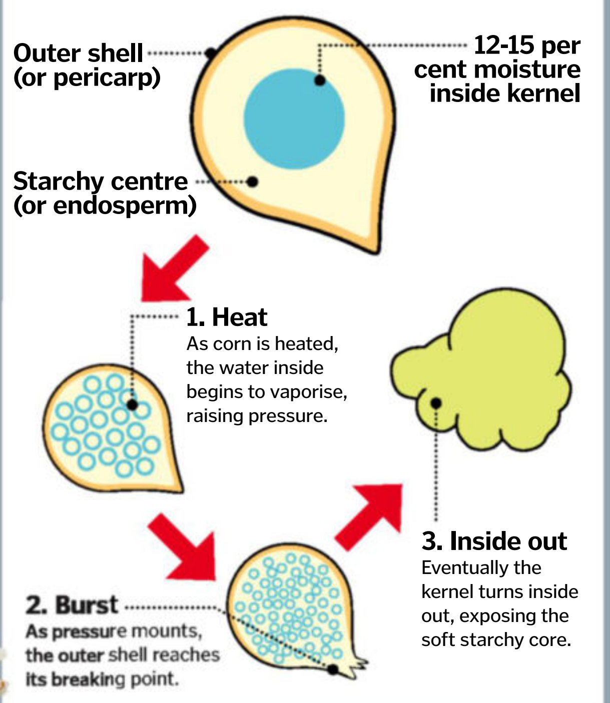
The lid of these devices is quite light and often on a hinge, so that as the popped kernels build up inside the chamber the lid lifts, letting you know the popcorn is ready.



When put under a little heat, corn can't handle the pressure so essentially bursts, turning inside out

Popping corn in action

See, step by step, how this movie snack is made



"The stiffness of the limbs makes the compound bow more energy efficient than other designs"

The compound bow

Discover how new-and-improved technology has transformed the traditional bow and arrow into a whole new beast…

The power of the compound bow comes from its construction, comprising three components: a riser and two limbs. The riser is the central part of the bow that is held and is made of aluminium alloy, or carbon fibre, for maximum strength. The limbs are bolted to the riser and are made of a more flexible composite, allowing them to bend to store energy as the bow is drawn.

The stiffness of the limbs makes the compound bow much more energy efficient than other designs, with hardly any vibration. The composite construction also provides an advantage over wooden alternatives because it is much less affected by temperature and humidity, enabling the archer to shoot accurately in varying weather conditions.

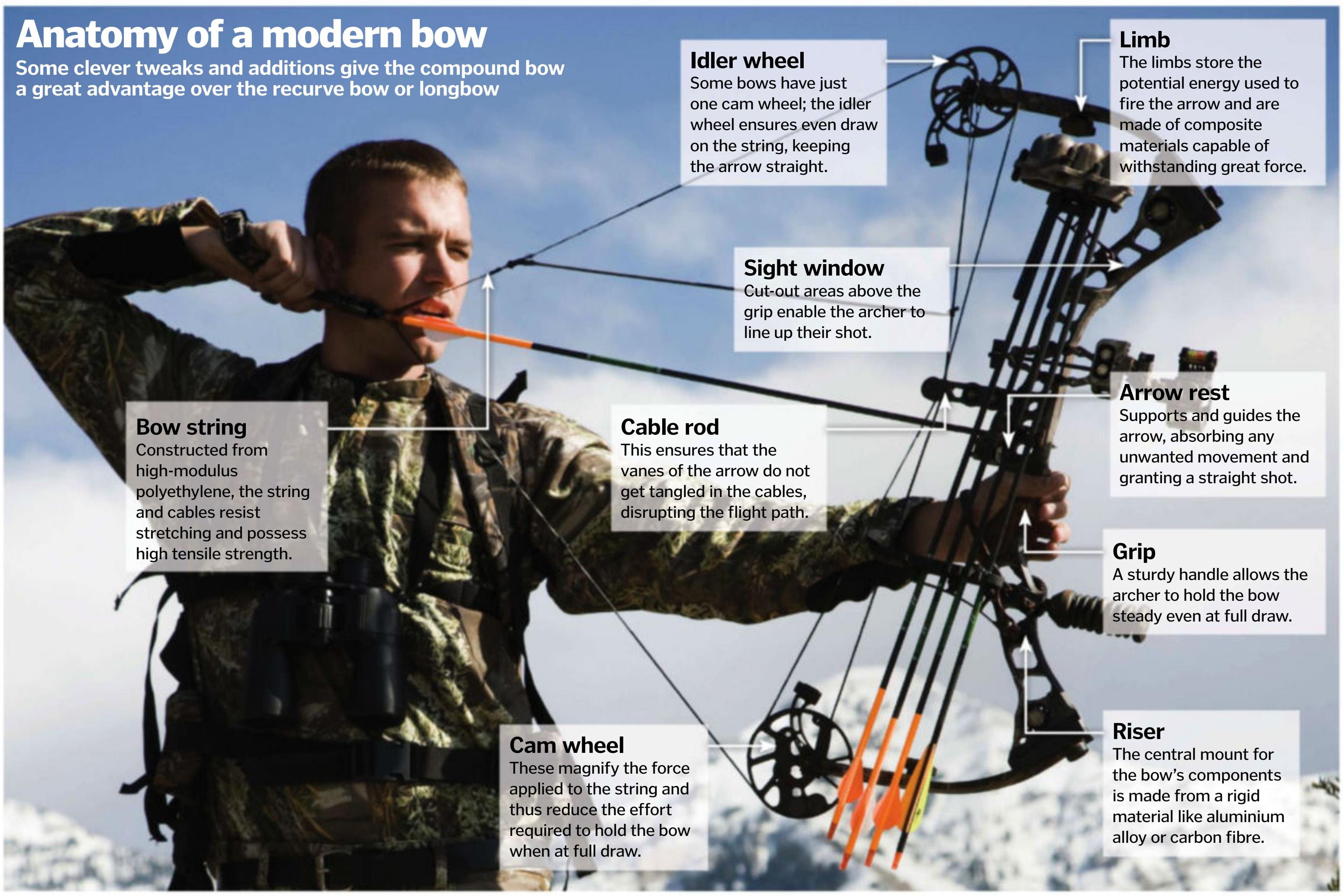
However, the rigidity of the compound bow would make it incredibly hard to draw if the strings were attached directly to the limbs, so a pulley-driven levering system is used. As the string is drawn, the pulleys take in the cables, which draws the limbs of the bow together, storing energy. The system uses asymmetrical cams, so that as the string goes beyond 50-80 per cent of the draw length – towards the point at which the arrow is ready to fire – the amount of force needed to pull the string is reduced. This allows the archer to hold the bow at full draw for longer, granting steadier shooting.

Beyond the bow…

To line up distant shots, archers often use sights with fibre-optic pins – different-coloured pins are set for varying distances, allowing the archer to adjust the shot. Scopes can also be added to magnify the target and increase aiming accuracy. Instead of using their fingers to draw the string, compound bow archers often use a mechanical release. Shaped like a small pincer, the release fits into the hand and pinches the string, enabling the bow to be fired more smoothly; using a release like this makes each shot much more consistent and predictable. Reducing vibration is also important in archery, as any unwanted movement will disturb the path of the arrow. Competitive archers and hunters often attach dampeners to the bow to nullify vibrating.

Anatomy of a modern bow

Some clever tweaks and additions give the compound bow a great advantage over the recurve bow or longbow



DID YOU KNOW? *The first endoscope, called the light conductor, was made in 1806 and used candles as its light source*

Endoscopic exploration

The technology allowing us to examine inside the body like never before

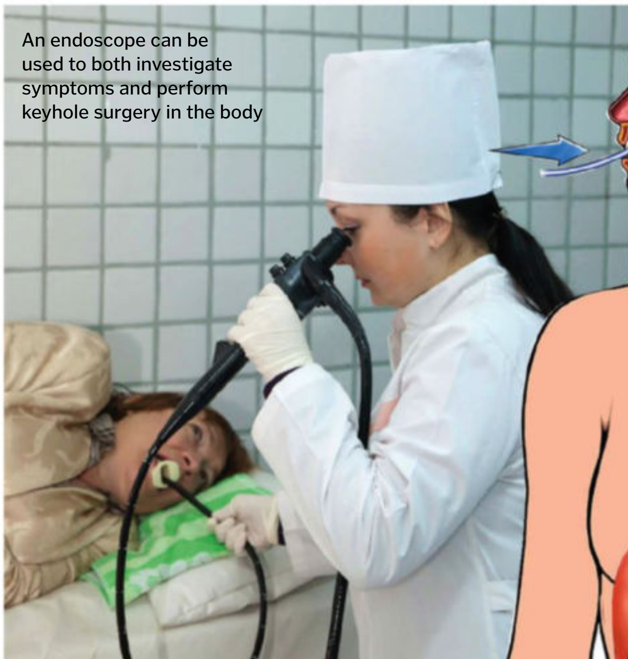
An endoscope enables surgeons to explore the human body without making large, invasive incisions.

At the end of the endoscope there is a light source and an objective lens. Light is transmitted through the endoscope via a bundle of fibre-optic cables, which clearly illuminate the surgical site. The reflected light is then focused onto a second fibre-optic bundle by an objective lens. The bundle typically contains between 3,000 and 20,000 fibres just a few micrometres thick, which allow the light to be 'bent' as the endoscope flexes, transmitting images to a screen at the other end for viewing.

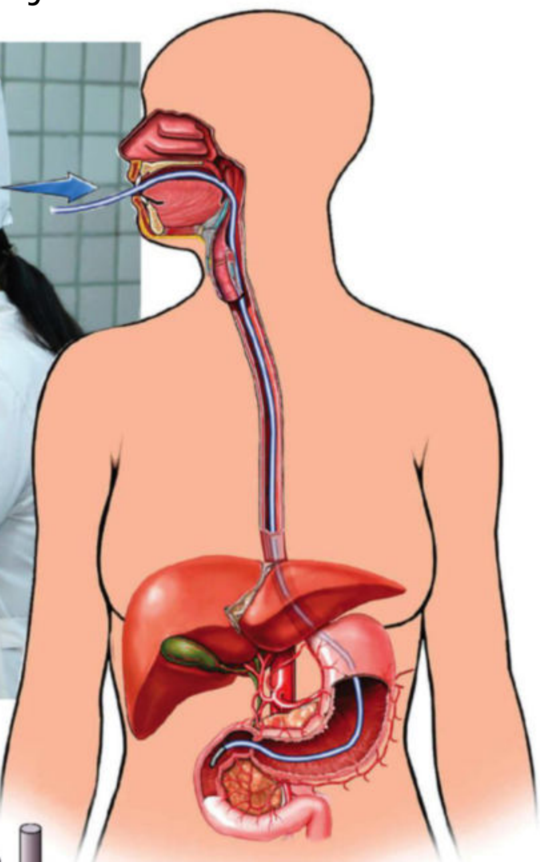
Two or more flexible wires, known as 'Bowden cables', run down the outer edges of the endoscope. These consist of an inner steel cable, which moves relative to a hollow outer casing, transmitting a force along the length of the device – much the same as a bicycle's brake cables. This means that the endoscope can be bent and twisted through tight gaps.

Endoscopes are not just cameras though – they also carry instruments which can perform mini surgical procedures. Due to the small size of the tube, none of the instruments exceeds three millimetres (0.12 inches) in diameter, but even at this micro scale an array of useful tools can be included.

Many endoscopes feature forceps, which can be used to take biopsy samples, while a few even have lasers, allowing the surgeon to seal blood vessels as they are cut to prevent excessive internal bleeding.



An endoscope can be used to both investigate symptoms and perform keyhole surgery in the body



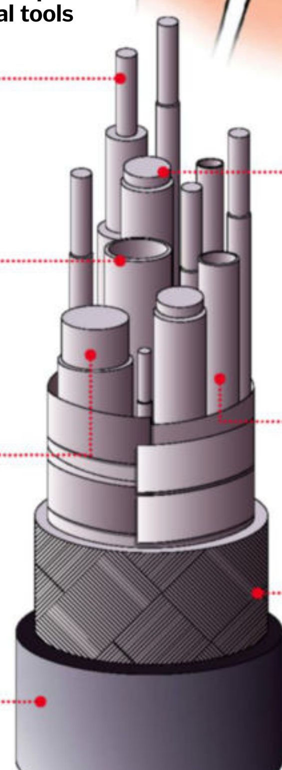
Not hard to swallow...

Despite their long, flexible tubes, traditional endoscopes are unable to reach the central portions of the small intestine – which is seven metres (23 feet) long. Instead of making an incision, surgeons can use a capsule endoscope.

A capsule endoscope is the size of a tablet and contains a camera, a light source and a wireless transmitter. The patient fasts for 24 hours to ensure that their digestive system is empty, and then the capsule is swallowed. As it moves through the digestive tract the light source illuminates the bowels, enabling the camera to record images, which are then transmitted via Bluetooth to a data recorder worn on a belt. The cameras are disposable and pass out of the body naturally, avoiding any invasive procedures.

Inside an endoscope

Beneath the outer layer, an endoscope is packed with miniaturised surgical tools



"A fracking well uses millions of litres of water per frack, putting pressure on local water resources"

Hydraulic fracturing

Controversial but effective, fracking enables us to tap into shale gas reserves trapped deep underground, but what does this mining process entail?

As we exhaust more easily accessible natural gas reserves, countries across the globe are increasingly turning to shale gas. But how do you release gas that's imprisoned in millions of tiny pores inside shale rock, deep beneath Earth's surface? The answer is hydraulic fracturing, or fracking.

Fracking involves drilling deep into rock and pumping a highly pressured jet of water, sand and chemicals down the wellbore. This forces a network of tiny cracks to open up and spread through the impermeable rock, allowing pockets of gas within the rock to seep out.

The main ingredient that makes up fracking fluid is water. Since water is incompressible, it can pass on the extreme pressures needed from the pump to the shale rock over 2,000 metres (6,560 feet) below. Sand or ceramic beads act as 'proppants', holding the cracks open after the pressure drops and while the gas is collected.

Finally, a cocktail of different chemicals is added. Their uses range from averting micro-organism growth to preventing corrosion of metal pipes, maintaining fluid viscosity and reducing friction during extraction.

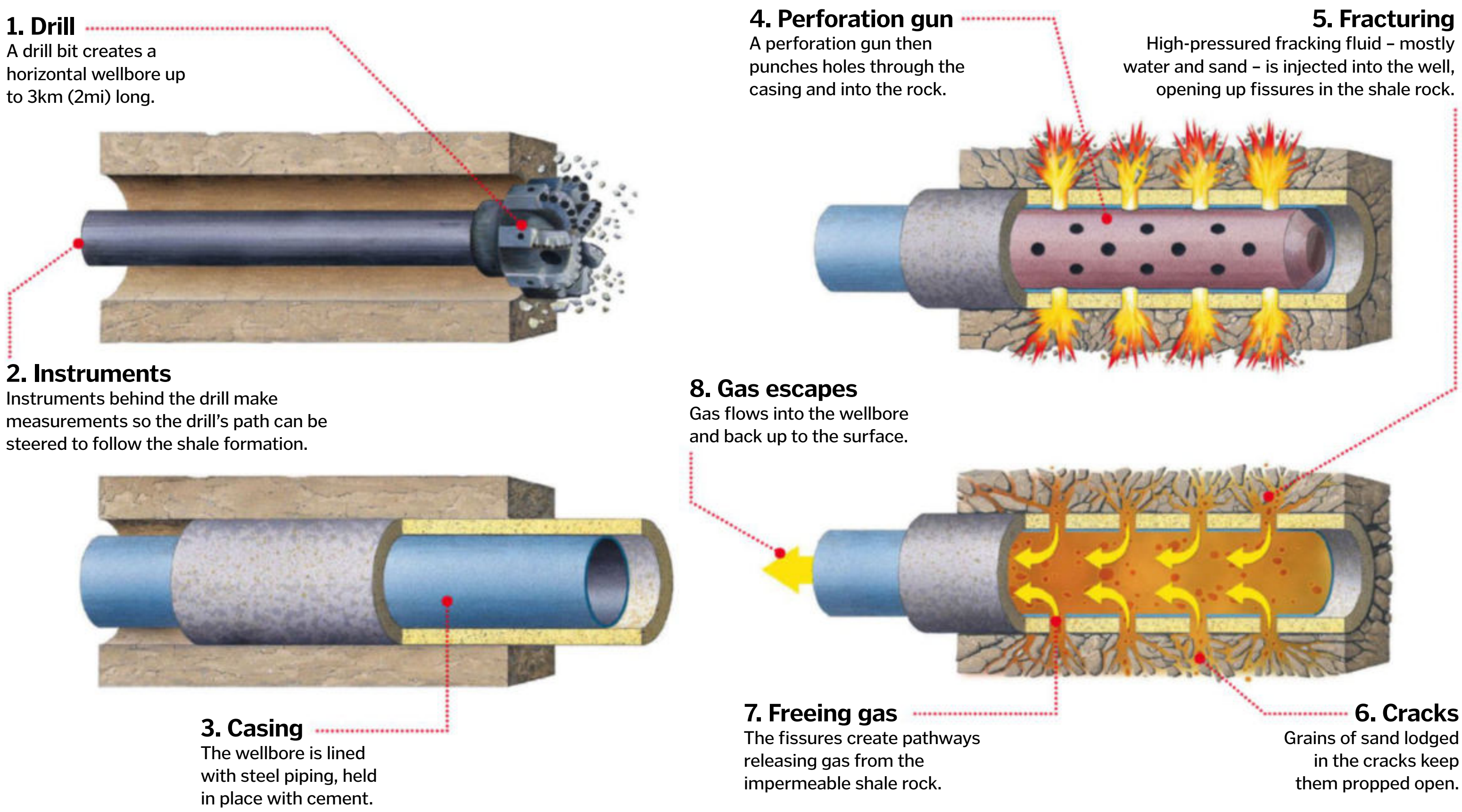
Hydraulic fracturing was first used in the 1940s, but is far more efficient today. The advent of horizontal drilling in the Nineties, for instance, made wells far more productive, making the operation economically viable.

While fracking has allowed governments to unlock previously unreachable and abundant shale gas resources, it has sparked concerns among some geologists and conservationists.

A fracking well uses millions of litres of water per frack, putting pressure on local water resources. Around half of the fracking fluid remains in the rock and, although much deeper than groundwater, some fear it could, over time, contaminate drinking supplies. The fluid recovered at the surface also needs to be disposed of safely. Finally, geologists must ensure fracking sites are far away from fault lines since they can increase the likelihood of earthquakes and tremors in at-risk areas.

Fracking in action

Take a closer look at how fracking releases shale gas from rock



5 TOP FACTS
FRACKING TRIVIA

Deep down
1 Fracking typically takes place at depths of 2,300 metres (7,700 feet) underground; that's equivalent to five Empire State Buildings (or seven London Shards) laid end to end.

Fracking the world
2 Hydraulic fracturing is now used at over 60 per cent of new oil and gas drilling sites around the globe. Fracking has been used over a million times and counting.

Shale gas giant
3 China has the largest reserves of recoverable shale gas anywhere in the world, sitting on an estimated 35 trillion cubic metres (1,250 trillion cubic feet) of the stuff.

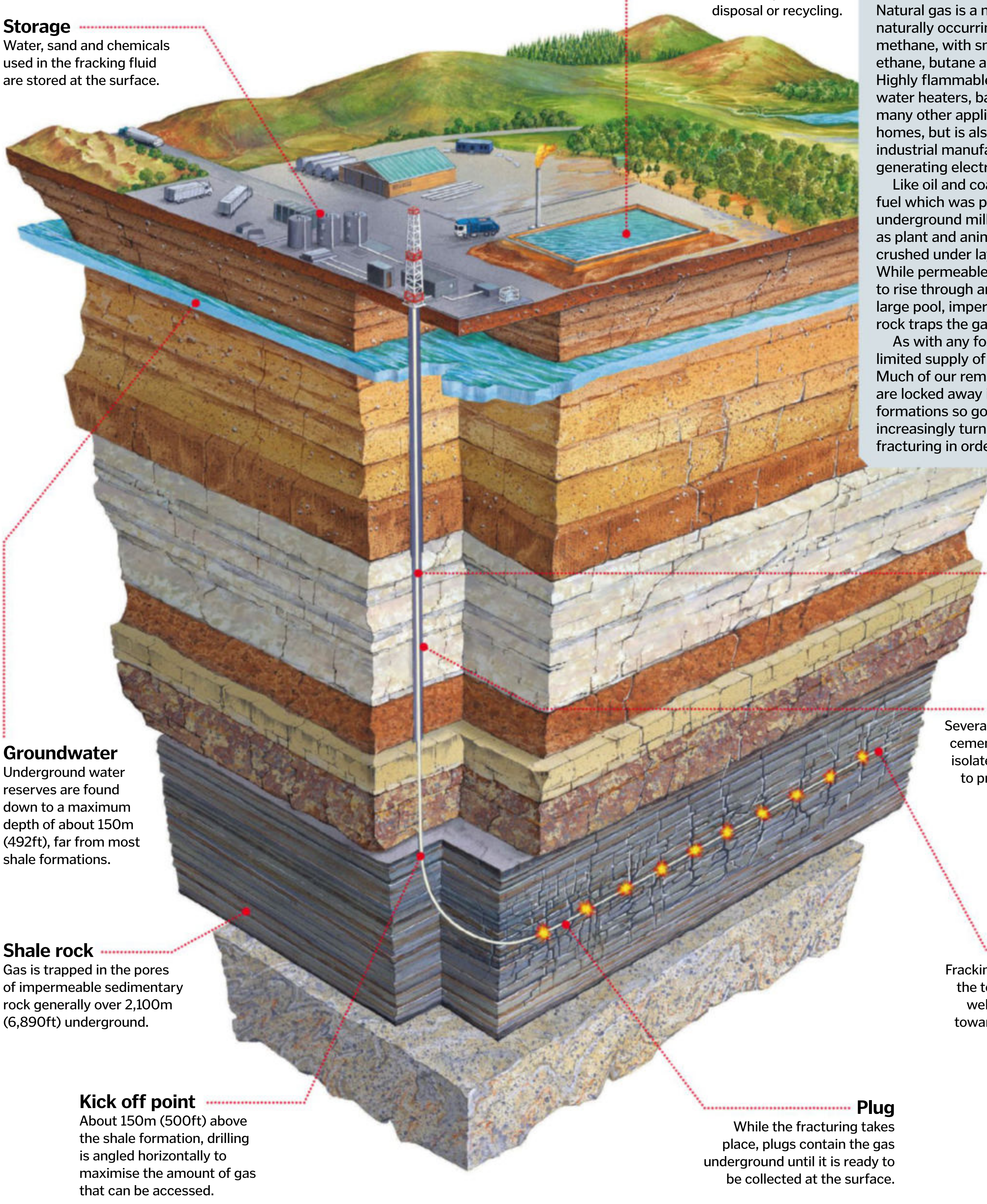
High-pressure job
4 Pumps inject fracking fluid at pressures of up to 1,050kg/cm[2] (15,000psi); that's about the same as the pressure of a male elephant balancing on a postage stamp!

Running out
5 At the rate we're currently using natural gas, experts predict that we'll have used up our planet's reserves by 2065, increasing the urgency to find new sources of energy.

DID YOU KNOW? *Gas companies add mercaptan (which smells like rotten eggs) to make odourless natural gas detectable*

Drilling for shale gas

Take a trip deep down inside a shale gas wellbore



A focus on natural gas

Natural gas is a mixture of four naturally occurring gases: mostly methane, with smaller amounts of ethane, butane and propane. Highly flammable, it fuels stoves, water heaters, barbecues and many other appliances in our homes, but is also used for industrial manufacturing and generating electricity.

Like oil and coal, gas is a fossil fuel which was produced underground millions of years ago as plant and animal matter was crushed under layers of sediment. While permeable rocks allow gas to rise through and collect in a large pool, impermeable shale rock traps the gas in tiny bubbles.

As with any fossil fuel, there is a limited supply of gas on Earth. Much of our remaining reserves are locked away in shale formations so governments are increasingly turning to hydraulic fracturing in order to extract it.

THE WORLD'S BIGGEST VEHICLES

These goliath machines are designed for maximum muscle power and maximum efficiency, but how do they work?

Believe it or not, the engineers, inventors and manufacturers who dream up the world's most gargantuan vehicles aren't in the business of glory hunting and collecting world records. In all cases, they are actually responding to an engineering challenge: whether it's how to shift millions of tons of mining debris most efficiently, how to transport tens of thousands of shipping containers using the least amount of fuel, or how to deploy tanks and troops into hostile territory with speed and stealth.

Even Howard Hughes' famous Spruce Goose, the whale of a wooden plane that dwarfed the biggest aircraft of its day, was designed for a purpose: to see if it was possible to transport large battalions of American troops by air to WWII battle zones in Europe and Asia.

Some mammoth machines are built to serve a single role, like the crawler transporters employed by NASA to slowly move super-heavy rocket technology from the assembly hangar to the launch pad. Or the Antonov An-225 – the world's largest aeroplane – which was specifically designed to transport another huge vessel: Russia's Buran space shuttle.

When the COO of shipping company Maersk was asked about the prestige of owning the biggest container ship in operation, he said he was more proud to own the world's most efficient vehicle. Able to move 18,000 containers halfway across the planet, the slow-moving Triple E will save the company billions in fuel costs and lower its carbon footprint. Being the world's biggest has its advantages, of course, but it also comes with many challenges…

Sea monster

Maersk Triple E, 2013 – present

The cavernous cargo holds of container ships are measured in TEUs – 20-foot equivalent units. Each TEU represents one standard six-metre (20-foot)-long shipping container, the 'intermodal' boxes that can be lifted by crane from ship to train and from train to truck. The Maersk Triple E, which sailed its maiden voyage from Asia to Europe on 15 July 2013 can hold 18,000 shipping containers – enough to transport 111 million pairs of shoes; Maersk now has 20 more Triple Es on order from Korean shipbuilder Daewoo. The three 'E's in the ship's name stand for economy of scale, energy efficiency and environment. With a maximum speed of 23 knots (42.5 kilometres/26 miles per hour), the Triple E may not be the fastest vessel around, but it consumes 35 per cent less fuel than its smaller rivals and produces 50 per cent less CO_2 per container. While it is a giant, its dimensions remain practical, meaning that it can still navigate the world's major ports and canals.

The statistics…

Maersk Triple E

Length: 400m (1,312ft)
Width: 59m (193ft)
Height: 73m (240ft) above baseline
Deadweight: 165,000 tons

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Watch a slow-motion video of a Saturn V launch

www.howitworksdaily.com

DID YOU KNOW? To construct a single Triple E container ship, Korean shipbuilder Daewoo uses more steel than eight Eiffel Towers!

The statistics…

Antonov An-225

Length: 84m (275.5ft)

Wingspan: 88.4m (290ft)

Height: 18.1m (59ft)

Empty weight: 285,000kg (628,317lb)

Winged juggernaut

Antonov An-225, 1988 – present

The Antonov An-225 Mriya (Mriya means 'dream' in Ukrainian) is the world's biggest aircraft. Nearly the length of a football pitch, this six-engine giant was designed to transport the Buran spacecraft – the Soviet space programme's version of NASA's Space Shuttle. The first and only An-225 was finished in 1988 and is still in service. With a maximum flying weight of 640 tons, the An-225 has hauled several record-breaking loads, including the heaviest-ever single piece of cargo – a 187-ton generator for a gas power plant – and the world's longest pieces of cargo – a pair of wind turbine blades each measuring 42 metres (137 feet). Rather than using a rear cargo ramp to load the 1,200 cubic metres (42,000 cubic feet) of pressurised cabin space, the nose of the An-225 pivots upward at a 90-degree angle. Among this aircraft's many marvels is its massive landing gear which features 32 individual wheels.

NASA's pair of crawler transporters recently received new ball bearings, ensuring 50 more years of service

The statistics…

NASA crawler

Length: 40m (131ft)

Width: 34.7m (114ft)

Height: 8m (26ft)

Weight: 2,858 tons

Tracked titan

NASA crawler, 1964 – present

There are 6.8 kilometres (4.2 miles) of road between the towering Vehicle Assembly Building and Launch Pad 39B at the Kennedy Space Center in Florida. For more than four decades, a pair of goliath crawler transporters (CTs) have carried NASA's rockets – from the Saturn V to the Space Shuttle – down that stretch of pulverised gravel. The CT is in no hurry, taking a leisurely six hours to make a one-way trip. The massive machine looks like four military tanks with a parking lot strapped to their back. The pair of CTs was designed by a coal-mining company in the Sixties and were built to last – both still have their original engines: twin 2,050-kilowatt (2,750-horsepower) diesel beasts. The CT is scheduled to haul NASA's new SLS rocket to Pad 39B in 2017. When the weight of rocket and mobile launching unit are added to the heft of the CT itself, there will be 9.6 million kilograms (21.2 million pounds) on the move.

"The Russian-made Zubr can transport up to 500 troops in its massive 400m² [4,300ft²] cargo hold"

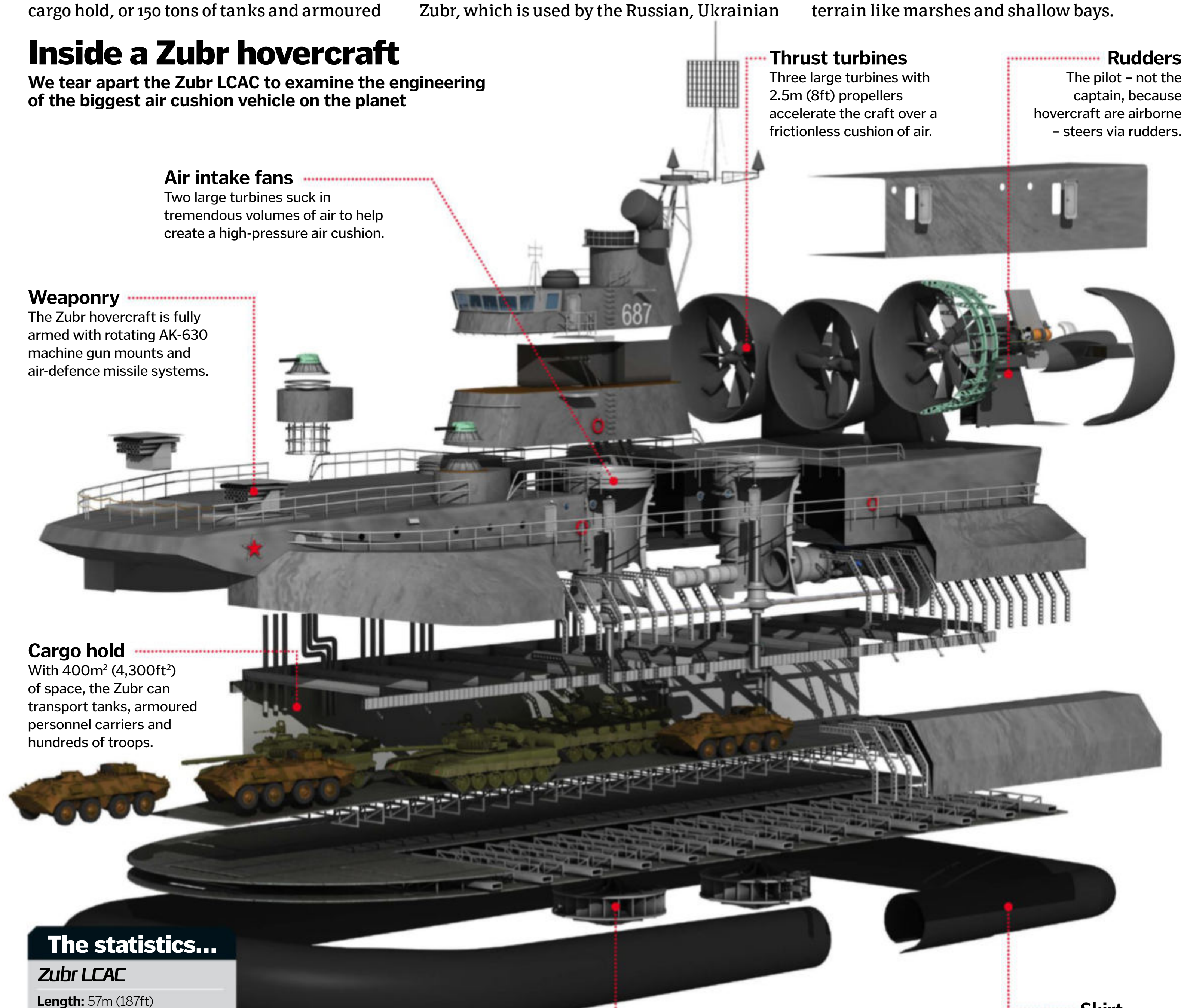
Herculean hovercraft

Zubr LCAC, 1988 – present

The Zubr-class hovercraft is the largest of a new fleet of amphibious military vessels called landing craft air cushion (LCAC) designed to access difficult shorelines. The Russian-made Zubr can transport up to 500 troops in its massive 400-square-metre (4,300-square-foot) cargo hold, or 150 tons of tanks and armoured personnel carriers. The Zubr gets its lift from two five-metre (16-foot) turbines, allowing the steel pontoon to float on a cushion of air. Three additional turbines provide thrust, propelling the hovercraft to a maximum speed of nearly 70 knots (129 kilometres/80 miles per hour). The Zubr, which is used by the Russian, Ukrainian and Greek navies, is armed with anti-aircraft missiles, anti-personnel missiles, air-defence guns capable of unloading 6,000 rounds per minute and mine-laying equipment. LCAC hovercraft give naval forces access to 70 per cent of the planet's shoreline, including tricky terrain like marshes and shallow bays.

Inside a Zubr hovercraft

We tear apart the Zubr LCAC to examine the engineering of the biggest air cushion vehicle on the planet



The statistics...

Zubr LCAC

Length: 57m (187ft)

Width: 25.6m (84ft)

Displacement (fully loaded): 555 tons

182mn

TRIPLE E iPAD CAPACITY

If you stacked each of the Triple E's 18,000 containers on top of each other, the pile would reach 47 kilometres (29 miles) into the sky. Not only that, but the Triple E could carry a whopping 182 million iPads!

DID YOU KNOW? Typhoon-class subs are big enough to include a games room, gym, sauna and even a swimming pool!

Mega chopper

Mil Mi-26, 1977 – present

The Russian-made Mil Mi-26 is the largest of the 'heavycopters' – high-altitude, high-capacity helicopters that can transport up to 90 troops and heavy machinery to places that no plane or train can access. The Mi-26 gets its power from twin 8,500-kilowatt (11,400-horsepower) turbines that share the load of driving a massive eight-bladed rotor. If one engine fails, the other can keep the chopper flying at full speed. The Mi-26 is listed with a maximum service altitude of 4,600 metres (15,091 feet) and a maximum payload weight of 20,000 kilograms (44,092 pounds). Although initially used exclusively for military purposes, there are now more than 300 Mi-26 helicopters in service around the world, transporting heavy earth-moving equipment to flood zones, rescuing stranded aircraft and engaging in aerial firefighting, among other operations.

The statistics...

Mil Mi-26

Length: 40m (131ft)
Rotor diameter: 32m (105ft)
Height: 8.1m (26.6ft)
Weight: 28,200kg (62,170lb)

Super sub

Typhoon, 1981-2014

The Typhoon-class submarine is the largest of the Soviet Union's nuclear fleet. The Typhoon, nicknamed Akula (Shark), is a nuclear sub in two ways: first, its steam turbines are powered by an on-board nuclear water reactor; and second, it carries a payload of up to 20 ballistic missiles, each equipped with ten nuclear warheads. Despite its size, the Typhoon is very quiet, aided by an innovative multi-hulled design and sound-dampening exterior tiles. The Typhoon was built to conduct long missions under thick layers of Arctic ice; indeed, it can remain submerged for up to 120 days and the blade-like sail makes for an effective ice-breaker. Only six Typhoon-class subs were ever built and the last two are scheduled for decommission in 2014.

The statistics...

Typhoon sub

Length: 175m (574ft)
Width: 23m (75ft)
Draught: 12m (38ft)
Displacement: 34,342 tons

Largest launcher

Saturn V, 1967-1973

It's hard to imagine the sheer size of the Saturn V, standing 18 metres (60 feet) taller than the Statue of Liberty. The Apollo astronauts in their tiny capsule were essentially strapped to a tower of rocket fuel. At launch, the first stage of the three-stage Saturn V generated 34.5 million Newtons (7.6 million pounds-force) of thrust, burning through 2.1 million kilograms (4.7 million pounds) of propellant in less than three minutes. At 68 kilometres (42 miles) up, the first stage detached and the second stage ignited, thrusting the rocket and its payload into near orbit. The third stage burned for only two minutes, transporting the capsule into 'parking orbit' 190 kilometres (118 miles) into space. On the ground, the Saturn V weighed 400-plus elephants, but packed enough power to carry 43,500 kilograms (95,900 pounds) of cargo to the Moon.

The statistics...

Saturn V rocket

Length: 111m (363ft)
Diameter: 10.1m (33ft)
Weight (fully fuelled): 2,800 tons

1. SMOKIEST

Cigarette
Smoke leaving a cigarette begins with a smooth laminar flow, but as both its velocity and length increase, it becomes more and more turbulent.

2. SPORTIEST

Golf ball
Golf balls are dimpled to *create* turbulence. This is because smooth surfaces lead to a region of low pressure forming behind which results in high drag.

3. WINDIEST

Aeroplane
Clear-air turbulence (CAT) occurs when atmospheric warm and cold air are mixed by wind. This is the type of turbulence we experience when flying.

DID YOU KNOW? Mountain waves are a form of turbulence produced when strong winds hit a peak and break over the summit

The technology behind in-car surround sound

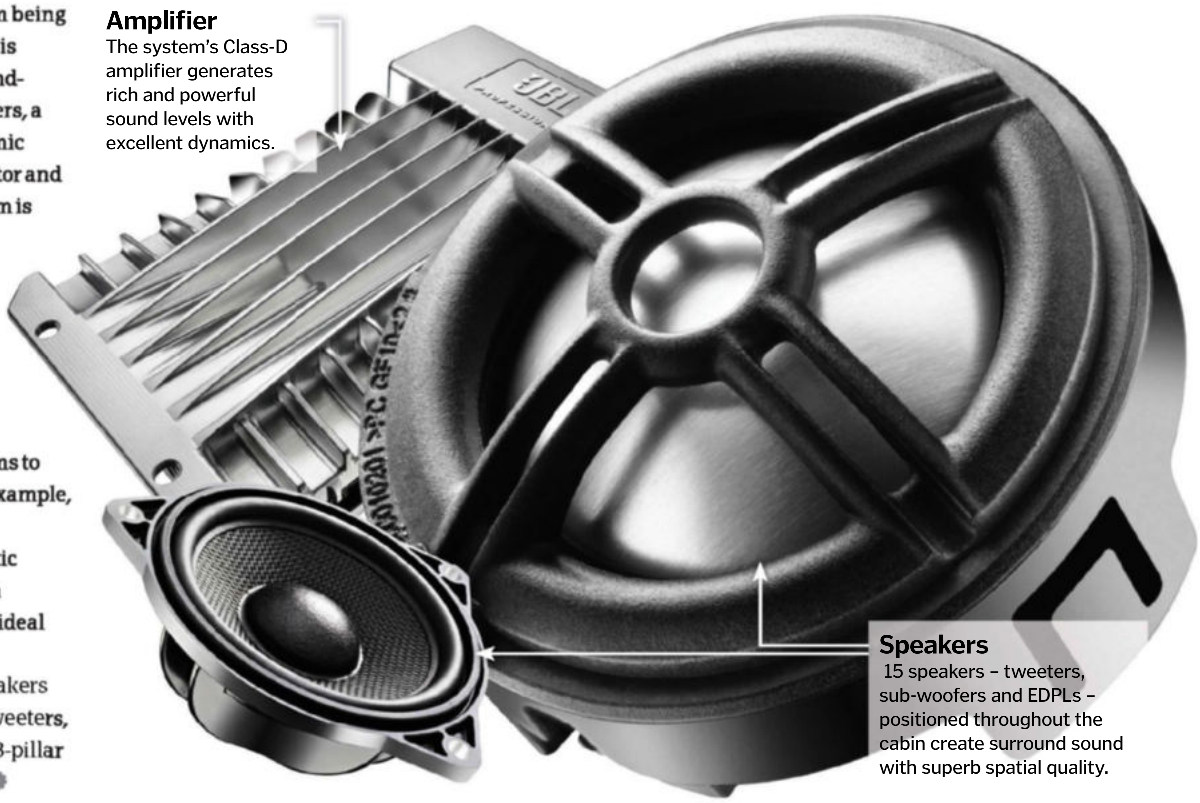
Find out how next-gen surround sound has made a quantum leap…

A new state-of-the-art audio system being installed into Ferrari's FF supercar is setting new precedents for surround-sound technology. Featuring a total 15 speakers, a 1,280-watt amplifier, a series of electrodynamic planar loudspeakers (EDPLs), a signal extractor and aesthetic engine, this surround-sound system is unparalleled in any other vehicle.

While the EDPLs – which use a very thin film diaphragm to produce sound waves – and multitude of other speakers are impressive, what is really key to the new system's cutting-edge credentials are the signal extractor and aesthetic engine.

The former works by using audio algorithms to pick out signal streams from any track – for example, individual voices or instruments – and then fine-tunes them. From this point, the aesthetic engine takes over – a piece of software which reassembles the individual streams into the ideal acoustic structure for ultra-crisp audio.

Once the software has performed, the speakers are called into action, with a wide range of tweeters, woofers and EDPLs – the latter built into the B-pillar of the car – providing immersive playback.



Amplifier
The system's Class-D amplifier generates rich and powerful sound levels with excellent dynamics.

Speakers
15 speakers – tweeters, sub-woofers and EDPLs – positioned throughout the cabin create surround sound with superb spatial quality.

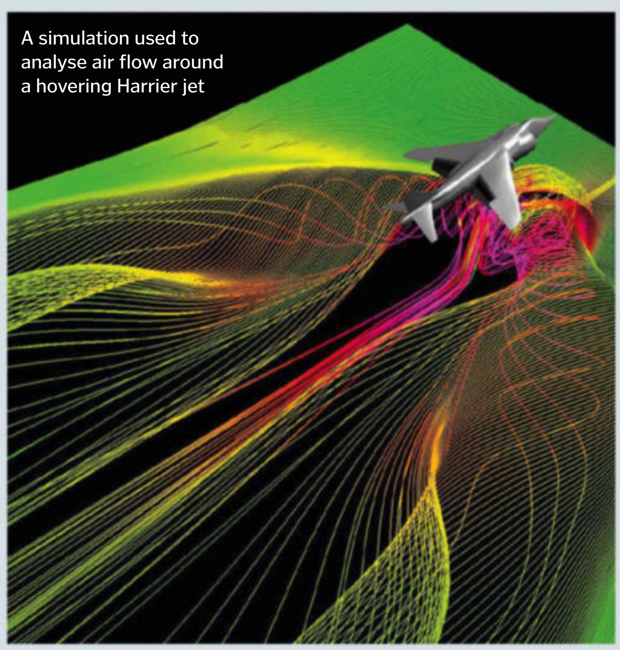
What is turbulence?

Strap in to discover what causes bumpy flights

Turbulence is a flow condition within a medium – such as air or water – in which local speed and pressure changes unpredictably within an overall stable flow direction. As such, turbulence is characterised by rapid changes of momentum diffusion and convection, as well as velocity. It is the result of a medium like air having unseen, intermingling layers moving at varying speeds and in many directions.

In general we are most familiar with turbulence while travelling on aeroplanes, when the cabin experiences a period of buffeting. This in-air bumpiness is referred to as clear-air turbulence (CAT) and is caused when atmospheric warm and cold air are mixed by high winds. Often occurring near jet streams, the segments of air have varying pressures due to their heat differential. CAT is invisible and so can occur suddenly without warning.

The severity of turbulence is measured in fluid mechanics by its Reynolds number. For example, if the medium's Reynolds number is less than 2,000, the medium's flow is laminar (ie steady, parallel layers), while if the number exceeds 2,000, then its flow is generally described as turbulent (ie disruptive, intermixing layers).



A simulation used to analyse air flow around a hovering Harrier jet

"Diesel engines are used because they offer far greater fuel economy"

Inside a ship's engine room

Take a look at the propulsion machinery on board one of the world's biggest cargo vessels

A ship's marine engineer is responsible for the propulsion systems on board vessels like the Amerigo Vespucci container ship in this photo. Propulsion machinery is contained in the engine room – usually at the lower end of the rear, or aft, of a ship. Immense engine power is required to turn the propellers that drive the vessel and, as well as the main engine (prime mover), there are also auxiliary machines like boilers and generators. The engines power the ship's electrical systems as well as turning the propellers for propulsion.

Diesel engines are used because, although they're less reliable and eco-friendly than gasoline engines, they offer far greater fuel economy – a key asset when your ship needs to travel for weeks and months on end.

There are three main layouts for ship-propulsion machinery: direct-coupled slow-speed diesel engines, medium-speed diesels with a gearbox drive to the propeller and steam turbines also with a gearbox. Regardless of the speed of the prime mover, for efficient operation the propeller shaft must rotate relatively slowly at 80-100 rotations per minute (rpm). Slow-speed diesels rotate at this speed, so the propeller shaft can be coupled directly with the crankshaft. Medium-speed diesels, however, can't be coupled with propellers as they rotate too fast – somewhere between 250-750 rpm; in these cases a gearbox is used to connect the engine and propeller shaft. Also requiring a gearbox to allow a slow drive speed for the propeller shaft is the steam turbine, which rotates much faster at up to 6,000 rpm.

THE STATS
VESPUCCI FIGURES

LENGTH	365.5m	ENGINE WEIGHT	2,300 tons	BEAM	51.2m
GROSS TONNAGE	152,991	POWER OUTPUT	81,222kW	SPEED	24.3 knots

DID YOU KNOW? *Italian explorer Amerigo Vespucci voyaged to the New World and lent his name to the 'Americas'*

© SPL

Brooklyn Bridge

One of New York's most recognisable landmarks, the Brooklyn Bridge was the first-ever steel-wire suspension bridge

Built between 1870 and 1883, the Brooklyn Bridge links Brooklyn and Manhattan by spanning the East River in New York City. Designed by a German immigrant, John Augustus Roebling, it was his son, Washington Roebling, and daughter-in-law, Emily, who actually oversaw most of the construction after John's unexpected death just months before building commenced.

The bridge consists of two main elements. Firstly, there are the two anchorages that are positioned either side of the river and between them are two towers (also known as piers) which stand some 84 metres (277 feet) high. Consisting of limestone, granite and cement, the towers – designed in a neo-Gothic architectural style – stand on concrete foundations that run 13.4 metres (44 feet) and 23.8 metres (78 feet) deep on the Brooklyn and Manhattan sides, respectively.

Secondly, the bridge itself is constructed from iron and steel-wire cables, with a layer of tarmac on the main deck. At 26 metres (85 feet) wide and 1,825 metres (5,989 feet) long, the Brooklyn Bridge was the longest suspension bridge in the world when first built and held the record for over 20 years. Roebling's design includes many redundancies, such as a diagonal stay system between cables and stiffening trusses, which make the bridge very safe; indeed, even if one of the main support systems were to fail altogether the bridge would sag, rather than completely collapse.

More unusually, the bridge also has its own nuclear fall-out shelter built into one anchorage. Having fallen out of use and been forgotten, the shelter was rediscovered in 2006, along with provisions from the Cold War era. Designated a National Historic Landmark in 1964, since the Eighties the bridge has been floodlit at night to highlight its distinct architectural features. Initially intended to carry motor vehicles, trains, street cars, bicycles and pedestrians, since the Fifties, the bridge has only taken cars, cyclists and foot traffic. Over 120,000 vehicles, 4,000 pedestrians and 3,100 cyclists cross it every day.

1,991m

LONGEST SUSPENSION BRIDGE

When completed in 1883, the Brooklyn Bridge's was a record holder, but today it has been superseded by the Akashi Kaikyo Bridge in Japan, with a main span of 1,991 metres (6,532 feet).

DID YOU KNOW? In 1884, showman PT Barnum paraded 21 elephants over the Brooklyn Bridge, proving its stability

The origins of suspension bridges

In a suspension bridge the deck – the load-bearing portion – is hung below suspension cables on vertical suspenders which bear the weight. Although bridges of this design first seem to have been invented in 15th-century Tibet, it was really the 19th century which saw their application on a massive scale.

The materials used in the construction of the Brooklyn Bridge were sourced in the US. The granite blocks were quarried in Maine and delivered to New York by boat. The wire rope and steel cable were produced in local factories, while the pigment used in the red paint with which the bridge was originally covered came from the mines at Rawlins, Wyoming.

The design and construction techniques employed in the Brooklyn Bridge have changed little in their essentials over the last century or so. Although at least 81 suspension bridges today are longer than the Brooklyn Bridge, they are all fundamentally the same – except that now the materials tend to be drawn from all over the globe rather than sourced locally.

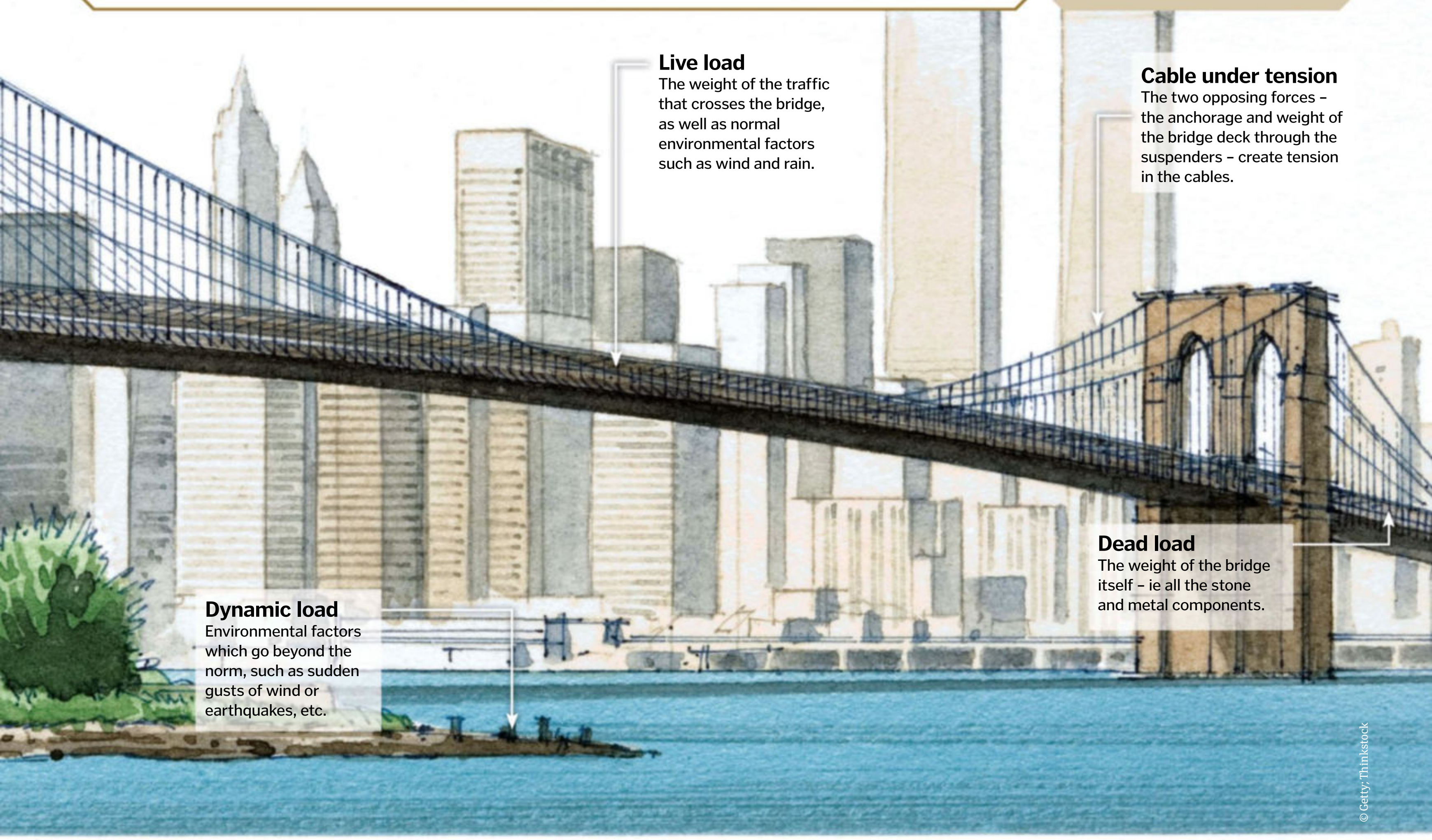
The Brooklyn Bridge during construction in the late-19th century

Cultural impact

Since its completion, the Brooklyn Bridge has inspired many an artist and poet. The modernist American poet Hart Crane, for example, famously published the ode *To Brooklyn Bridge* in 1930. Regarded as a wonder of its age, people flocked to see the structure's opening with a spectacular fireworks display and regatta in 1883 – a celebration which was repeated on its 100th anniversary.

Many people have jumped off the bridge as publicity stunts or suicide attempts, while others have got married on it. In 1919 the Caproni heavy bomber, which was then the world's largest aeroplane, was flown under the deck, while in 2003 it was the intended target of an Al-Qaeda terrorist plot.

The Brooklyn Bridge has also frequently appeared in Hollywood movies, such as *I Am Legend*, *The Dark Knight Rises* and *Godzilla*; most recently the bridge featured in *The Great Gatsby*.



79 When Vesuvius blows its top it destroys the cities of Pompeii and Herculaneum in Italy.

1815 The eruption of Mount Tambora in Indonesia is so huge it decreases global temperatures.

1883 Through its eruptions and subsequent tsunamis, Krakatoa claims an estimated 35,000 lives.

1902 The eruption of Mount Pelée on Martinique is one of the worst of the 20th century, killing about 30,000.

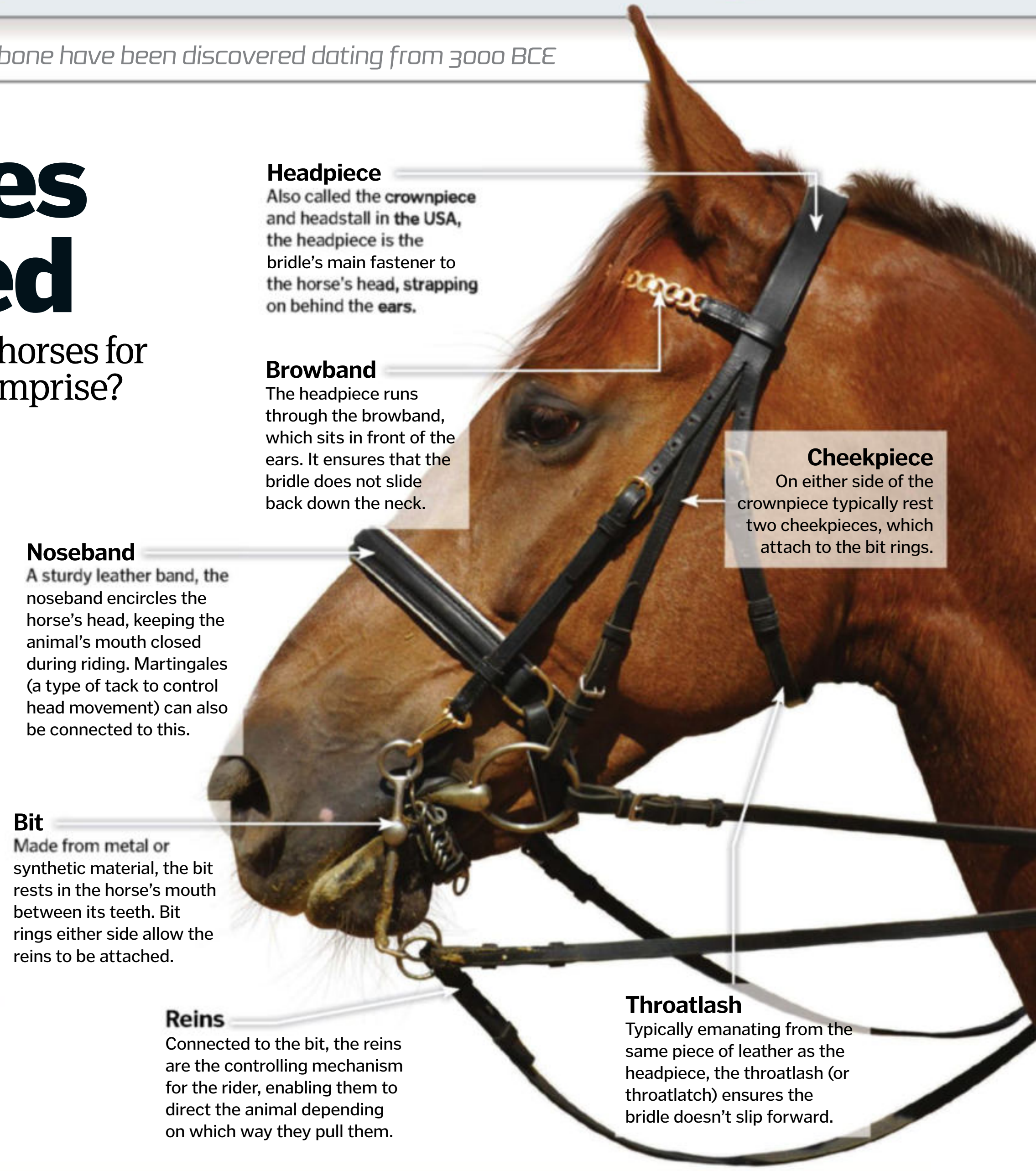
1985 The eruption of Nevado del Ruiz in Colombia is fairly small, but its mud flows kill several thousand.

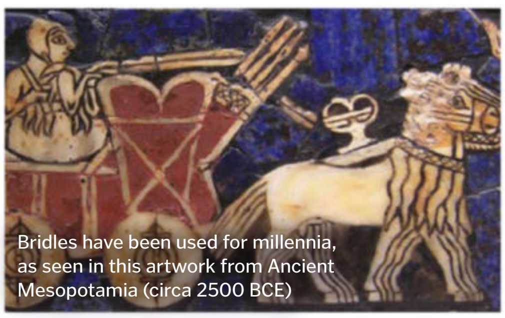
DID YOU KNOW? *Horse bits made from bone have been discovered dating from 3000 BCE*

How horses are steered

The bridle has helped us ride horses for millennia, but what does it comprise?

While the invention of the saddle circa 700 BCE allowed us to ride horses with more stability and comfort than ever before, it was the emergence of the bit – a metal bar placed between the horse's teeth – and bridle – a set of fasteners to secure the bit in place – over 4,000 years ago that truly granted equestrian mastery. From simple beginnings as nose rings with lengths of rope attached, the bit soon acquired increasingly more leather strapping until the bridle as we know it today emerged, allowing the bit and reins to be securely fitted to any sized horse. Today, various styles of bridle exist, each suited to different riding disciplines and events.





Bridles have been used for millennia, as seen in this artwork from Ancient Mesopotamia (circa 2500 BCE)

Why Krakatoa was heard across Earth

What caused the mega volcanic eruption in 1883 to be heard all around the world?

Krakatoa's super-explosive 1883 eruption was so loud because of its pressure wave reverberating around the planet over seven times. This was due to the colossal energy release from the volcano, which was equal to over 200 megatons of TNT – roughly four times as much as the largest-ever detonated nuclear bomb!

Indeed, the radiated pressure wave was so high that it ruptured the eardrums of sailors in the Sunda Strait in Indonesia, generated tsunamis almost 40 metres (131 feet) high and caused a mercury spike in pressure gauges attached to gasometers in the Batavia (modern-day Jakarta) gasworks, located nearly 160 kilometres (100 miles) away.

Krakatau (ie Krakatoa) is an island positioned between Java and Sumatra in Indonesia

"After the light-sensitive paper has been exposed… it is transferred to a tray of developer solution"

Darkrooms illuminated

We reveal the science and history behind the original photo laboratory

The darkroom was invented around the same time as photography in the early-19th century. Today it's often referred to as the 'Photoshop of the film age' and although they may not be as commonly used nowadays, darkrooms are still popular among traditional film photographers.

The idea of the darkroom came from the camera obscura – a darkened chamber that projected the outside view through a pinhole onto a flat surface like a wall. The concept of the camera obscura dates back to at least the fourth century BCE, but it was not until the 1800s that scientists had any success in capturing the projection as an image using chemicals.

In the early-1830s recording light using silver salts placed on glass plates and eventually paper had been successful. Louis Daguerre's famed process, which dates from around 1833, made it possible to capture stable images using chemicals that would develop the print onto plates. This method – later superseded by William Henry Fox Talbot's calotype process in 1841, which used paper instead of plates – paved the way towards the development of the traditional darkroom we know today.

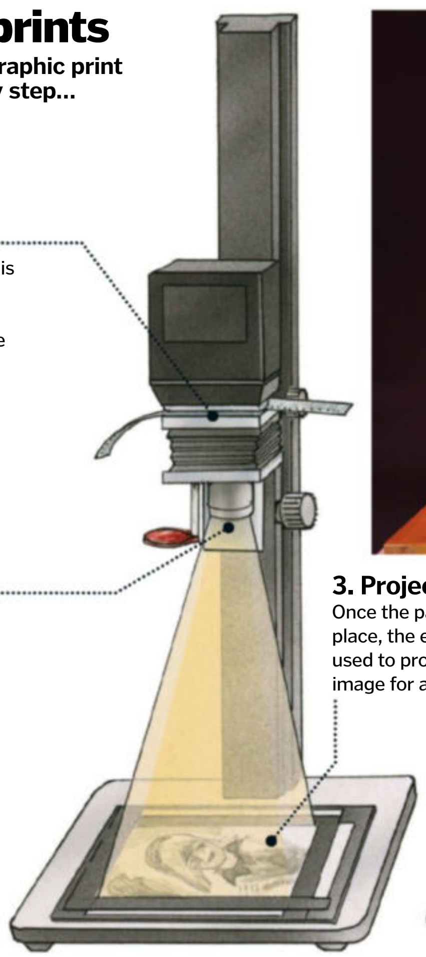
It was not until the invention of black-and-white film in 1885 that darkroom equipment, such as an enlarger, emerged. Working in a darkroom today, you'll find a lot of similar processes to those used over a century ago.

Once film has been developed into a negative using the same chemicals that are required to create prints, you can copy the image onto light-sensitive paper to produce a photograph. To do this, the negative is placed inside the enlarger and projected down. As negatives are reversed, dark areas on the negative will filter the light, which means parts of the paper are less exposed, resulting in highlighted areas in the photograph. Pale areas on a negative, on the other hand, represent the shadows, which means more light is let through to expose and darken the paper. After the light-sensitive paper has been exposed under the enlarger for a set amount of time, it is transferred to a tray of developer solution, where the image will appear. The paper can then be placed in a stop bath to halt the developing process before finally being stabilised with a fixer chemical.

Over the years many photographers have developed darkroom techniques to artistically alter the look of their images. Even today you'll find image-editing software, such as Photoshop, featuring tools mimicking classic techniques – like the Dodge and Burn tools – for bringing a retro look to our digital shots.

Developing prints

How to create a photographic print in the darkroom step by step…



1. Negative
The film negative is positioned inside the enlarger and projected onto the platform below.

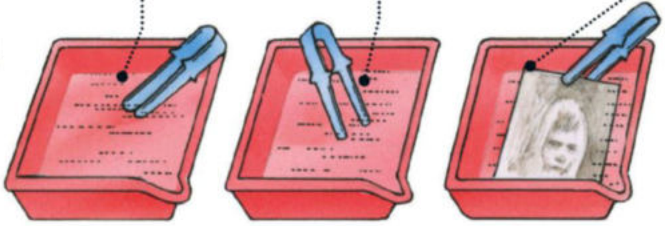
2. Focus/crop
The picture can be focused and cropped before placing the light-sensitive paper down.

3. Projection
Once the paper is in place, the enlarger is used to project the image for a set time.

4. Developer
After the paper has been exposed it will need to lie in a tray of developer fluid to start the process.

5. Stop bath
The paper is then dipped into a stop bath chemical to avoid it over-developing.

6. Fixer
Finally, the paper can be moved into what's known as a fixer, which effectively locks the image in place.



KEY DATES
PHOTOGRAPHY IN DEVELOPMENT

1800 Thomas Wedgwood is the first person to capture permanent images onto paper.

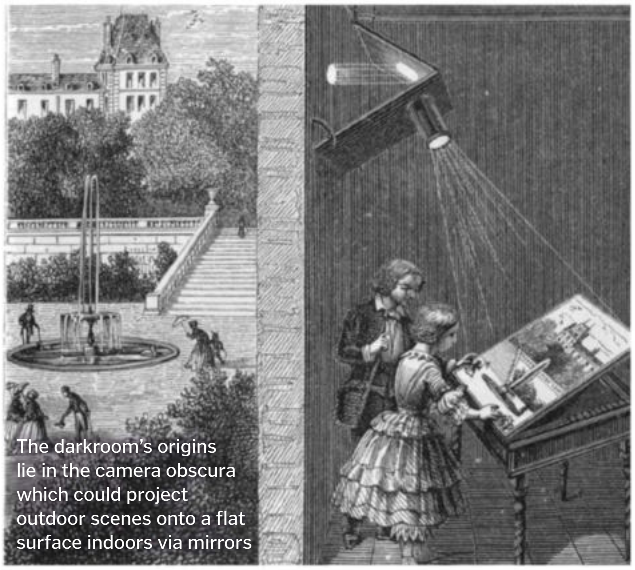
1826 Nicéphore Niépce invents heliography, producing the first snap with a camera obscura.

1833 Louis Daguerre devises his daguerreotype process, using light-sensitive plates and chemicals.

1841 William Henry Fox Talbot improves the photography field with his calotype process.

1885 George Eastman creates paper film and later celluloid film, which will be used in the first consumer cameras.

DID YOU KNOW? *Light-sensitive paper is not affected by red light, hence why it's used in a darkroom to help you see*



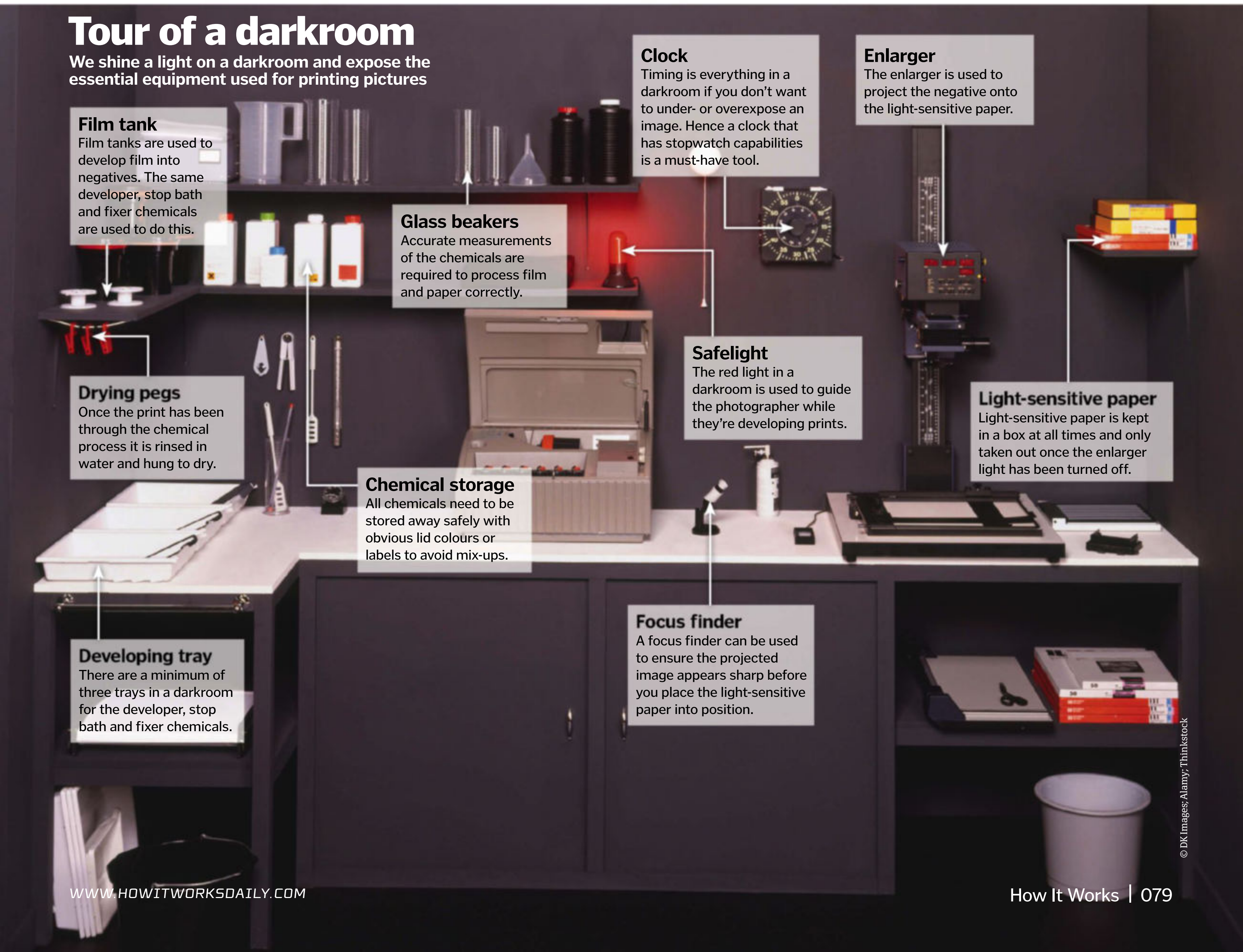
The darkroom's origins lie in the camera obscura which could project outdoor scenes onto a flat surface indoors via mirrors

Print chemistry

There are three chemicals commonly used to process film and develop photographs onto light-sensitive paper in the darkroom. These include a developer, stop bath and fixer.

The developer is the first stage after exposing the film or paper to light, and is designed to make the latent image visible by reducing the silver halides that have been exposed. A timer is used to prevent the paper from being over-developed and turning black.

The next step is the stop bath chemical which neutralises and halts the developer. The final stage is the fixer chemical, which stabilises the image and essentially fixes it to the paper.



Tour of a darkroom

We shine a light on a darkroom and expose the essential equipment used for printing pictures

Film tank
Film tanks are used to develop film into negatives. The same developer, stop bath and fixer chemicals are used to do this.

Glass beakers
Accurate measurements of the chemicals are required to process film and paper correctly.

Clock
Timing is everything in a darkroom if you don't want to under- or overexpose an image. Hence a clock that has stopwatch capabilities is a must-have tool.

Enlarger
The enlarger is used to project the negative onto the light-sensitive paper.

Drying pegs
Once the print has been through the chemical process it is rinsed in water and hung to dry.

Safelight
The red light in a darkroom is used to guide the photographer while they're developing prints.

Light-sensitive paper
Light-sensitive paper is kept in a box at all times and only taken out once the enlarger light has been turned off.

Chemical storage
All chemicals need to be stored away safely with obvious lid colours or labels to avoid mix-ups.

Developing tray
There are a minimum of three trays in a darkroom for the developer, stop bath and fixer chemicals.

Focus finder
A focus finder can be used to ensure the projected image appears sharp before you place the light-sensitive paper into position.

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

Are toucans related to woodpeckers?

Maria Bleaks

They belong to different families, but the same order: the Piciformes. Woodpeckers make up about half of the 400 species of Piciformes, but toucans form a much smaller family of around 40 species. Woodpeckers and toucans share an arrangement of toes that have two pointing forward and two pointing back to help them grip branches. Piciformes are also unusual in not having down feathers, even as chicks. But belonging to the same order isn't an especially close relationship. Toucans do use their huge beaks to reach into holes in hollow trees, but this is to steal eggs from other nests. They don't drill through the bark and mostly eat fruit, unlike woodpeckers which are all insectivores. **LV**

The keel-billed toucan lives in rainforests across South and Central America and can live for up to 20 years

Meet the experts...

Luis Villazon
Luis has a degree in zoology and another in real-time computing. He's been writing about science and technology since before the web. His science-fiction novel, *A Jar Of Wasps*, is published by Anarchy Books.

Giles Sparrow
Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in space writing. His latest book, published by Quercus, is *The Universe: In 100 Key Discoveries*.

Rik Sargent
Rik is an outreach officer at the Institute of Physics in London, where he works on a variety of projects aimed at bringing physics to the public. His favourite part of the job is what he calls 'physics busking'.

Alexandra Cheung
With degrees from the University of Nottingham and Imperial College, Alex has worked at many a prestigious institution including CERN, London's Science Museum and the Institute of Physics.

Dave Roos
A freelance writer based in the USA, Dave has written about every conceivable topic, from the history of baseball to the expansion of the universe. He has an insatiable curiosity for all things science and tech.

What is a stutter?

King George VI's stammer was the inspiration for 2010 movie *The King's Speech*

Laura

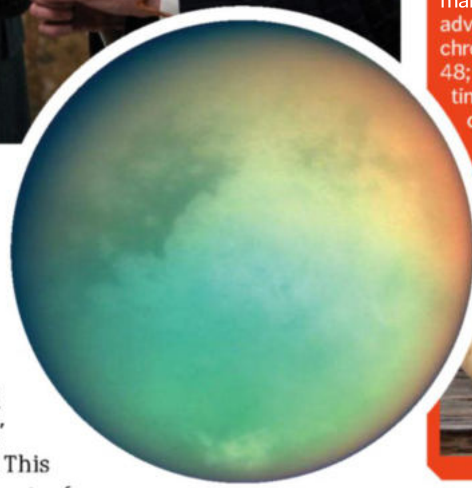
■ Stuttering, or stammering, is a disorder that can affect the flow and fluency of our speech. Common symptoms are the repetition of sounds, words or phrases – sometimes accompanied by rapid eye blinking and other facial tics. Although many young children stutter, only one per cent of adults have the disorder, and men are four times as likely as women to stutter. Speech language pathologists apply behavioural therapies to help stutterers slow their speech and breathing patterns to suppress the tics, although certain situations tend to aggravate the symptoms. When speaking with someone who stutters, don't attempt to finish their sentences – just be patient and calm. **DR**

Why is Titan so active?

Edward Stone

■ Astronomers think that Saturnian moon Titan's unusual geological activity is down to a combination of its size, its composition and its position in Saturn's system of moons. The second largest satellite in the Solar System, Titan is composed of rock and ice with a much lower melting point than the rocks of the inner planets – low enough for 'cryovolcanic' activity to gradually reshape the surface over time.

Titan's size also allows it to retain a substantial amount of heat from the collisions that formed it. Until recently, astronomers thought that this was the main driving force behind Titan's activity, but in 2012 maps of the moon's gravity field from the Cassini probe showed its shape is 'squashed' rather than spherical. This means that different parts of Titan experience different tidal pulls from Saturn and other nearby moons as it orbits the planet over a 16-day cycle. This constant tugging at the interior is now thought to generate much of Titan's internal heat. **GS**



5-SECOND FACTS

Humans are Earth's sweatiest animals

Most animals are limited by the amount of skin area that isn't covered with fur, and large animals rest during the hot part of the day or pant to keep cool. Our sweatiness may have evolved to enable us to run long distances when hunting speedy prey.

Potatoes possess more chromosomes than we do

This may be true, but that doesn't make them more complex or advanced. We have 46 chromosomes and potatoes have 48; it's just down to how many times chromosomes have broken down and formed extra ones during the species' evolutionary lineage – eg a goldfish has 94 chromosomes.

When was cutlery invented?

Duncan Mowbray

■ Stone knives date back around 2.5 million years, in contrast to the fork, which came much later – around the time of Ancient Greece. Early knives had a much broader use than just as a kitchen utensil – being used as weapons and tools, as well as to spear food. The first forks were originally used to pull food out of large boiling pots and not considered for putting food in your mouth – spoons, knives and hands were preferred for this.

One of the earliest known uses of forks as dining utensils was in Tuscany, Italy, in the 11th century, but this practice didn't catch on in the rest of Europe until the mid-1600s. After forks had found their place at the table, it was no longer necessary to make table knives with such pointed tips. **RS**

Why are pixels square?

Alistair Beckmann

■ Pixels are commonly square because squares fit together without leaving gaps, have sides of equal length and can be mapped to a grid with two axes – horizontal and vertical. If pixels were circles, there would be gaps when surrounded by neighbouring circles – not ideal for creating smooth images on a screen. Triangles and hexagons fit together too, but their sides follow more than two directions, requiring more processing power to form an image. Square pixels became the norm because there needed to be an industry standard to avoid compatibility issues over different devices. Square pixels stuck due to their simplicity. **RS**

What are bitcoins and who invented them? Find out on page 82

BRAIN DUMP

Want answers?

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5-SECOND FACTS

Iceland produces all its own electricity

Not only does Iceland produce all of its own electricity, but it does so with 100 per cent renewable sources. 75 per cent of its generated electricity comes from hydroelectric power stations and the other 25 per cent from geothermal plants.

A sneeze can travel at up to 100mph

A sneeze can exceed 161km/h (100mph), but it varies from person to person, as well as from sneeze to sneeze. On average, sneezes clock in between 64 and 161km/h (40 and 100mph), with most hovering around the 99km/h (60mph) mark.

Garter snakes have evolved an immunity to poisonous rough-skinned newts, but their prey is constantly evolving more potent tetrodotoxin to counter this

The curved, needle-like bills of hummingbirds and the shape of certain tropical flowers are a prime example of co-evolution

What is co-evolution?

Alun Gates

Co-evolution occurs when closely interacting species influence each other's development. In predator-prey or parasite-host relationships, two species can lock horns in an evolutionary arms race. Take the common garter snake, for example. Its favourite prey is a tasty but toxic newt which progressively evolves more potent toxins to deter its predator. As snakes with lower immunity to these toxins are killed or injured, the garter snake population evolves greater resistance to the poison. Increased predation means the newt is once again under pressure to become more poisonous, and the cycle repeats. Other species can co-evolve to co-operate, as occurs commonly with plants and their pollinators. Over 40 million years, the yucca moth and the yucca plant have become entirely dependent on one another. **AC**

What are bitcoins and who created them?

Traci Watson

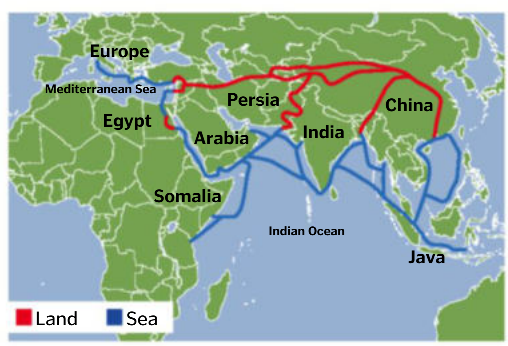
Bitcoin is a digital currency first described in 2008 by an anonymous developer with the pseudonym Satoshi Nakamoto. Bitcoin was created as a way of transferring funds internationally without having to pay bank charges or currency conversion fees. Independent of a central bank, the currency relies on peer-to-peer file sharing and is released into circulation by any computer running an application known as a bitcoin miner. Bitcoins are traded by an increasing number of online merchants around the world and, as of 2013, the value of the total number of bitcoins in circulation exceeds £655 million ($1 billion). **RS**

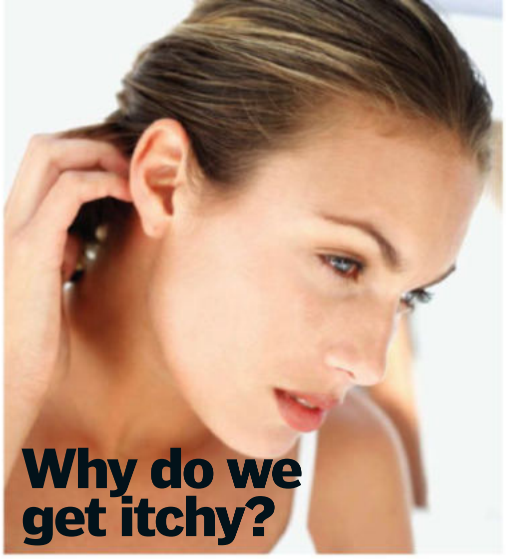
Where was the Silk Road?

Lucy Winner

The historic Silk Road was a series of land and sea trade routes that stretched for more than 6,400 kilometres (4,000 miles) to link the Far Eastern cultures of China to India, Persia, Arabia and as far west as the Mediterranean.

The Silk Road earned its name from the lucrative Chinese silk trade between the Chinese and Roman empires, which began around 200 BCE. For the next 1,500 years, the Silk Road would not only transport silk and spices, but share knowledge, culture and customs across unimaginable distances. Historians believe that algebra and other higher mathematics first arrived in the West via this route, as did the printing press and the magnetic compass. For safety and security, most traders travelled in caravans along established routes that linked towns and oases dotting the Central Asian steppes. **DR**





Why do we get itchy?

Chris Slade

An itch is the body's response to an irritant, but the evolutionary function of itching remains a mystery. Dead skin cells, hair, dust or the histamines our bodies produce during an allergic reaction trigger most everyday itches. Troublesome itching can be a symptom of skin conditions, while some itches are purely psychological. Once believed to be transmitted to the brain via the same circuitry as pain, itches actually have their own dedicated messengers. Recent research suggests we feel an itch when these specialised nerve cells release a molecule called neuropeptide natriuretic polypeptide b (Nppb). Our brain's immediate reaction is to scratch, dislodging the irritant or at least distracting us from the itch. Oddly though, scratching often *increases* skin irritation so it's best avoided or done gently. **AC**

Was Megatherium an ancestor of the bear?

Traci Watson

Megatherium's shaggy brown fur might remind you of a bear, but its closest modern-day relatives are actually tree sloths, anteaters and armadillos. The name Megatherium means 'giant beast', an appropriate name for a creature six metres (20 feet) long and weighing up to four tons. This giant sloth roamed South American grasslands and woodlands between 1.9 million and 10,000 years ago, possibly going extinct because of early human hunters. The brown bear's most recent ancestors are Ursus minimus (alive 5.3-1.8 million years ago) and Ursus etruscus (alive 5.3 million to 11,000 years ago), both of which were very similar in size to their modern-day counterparts. **AC**

An artist's impression of how Eris, Pluto and Ceres would size up to Earth and our Moon

How many dwarf planets are in the Solar System?

Duncan

Officially, there are currently five dwarf planets, though there are some other objects that probably deserve this title, and almost certainly many more to be discovered. In 2006, the International Astronomical Union invented the category 'dwarf planet' to encompass objects that follow independent orbits around the Sun, are massive enough to pull themselves into a spherical shape (so they're not asteroids or comets), but which (unlike proper planets) don't have enough gravity to 'clear out' smaller objects from around their orbits. The known dwarf planets are Ceres (the largest body in the Asteroid Belt) and Pluto, Haumea, Makemake and Eris (the last four all icy bodies orbiting in the outer Solar System beyond Neptune). **GS**

How do CRT, LCD and LED TVs differ?

Bob Tate

All TV technologies need to perform the same function: activating individual pixels on a screen to create an image. Cathode ray tube (CRT) is the oldest technology, emitting a beam of electrons through a vacuum tube onto a screen coated with photosensitive phosphor. The beam creates the image line by line, refreshing the entire screen 30 times per second. Liquid crystal display (LCD) technology relies on twisted liquid crystals that untwist when exposed to an electrical current. The liquid crystals are embedded in thousands of red, yellow and blue subpixels, twisting and untwisting to allow light to pass through the screen. LED TVs, meanwhile, are just LCDs that use LED bulbs as the source of backlight. **DR**

Why are scarab beetles such a widespread species? Find out on page 84

Why are scarab beetles so prolific?

April Kimball

■ About a quarter of all known animal species are beetles and the scarab beetles are one of the most diverse families of beetles. During the Jurassic period 200 million years ago, flowering plants evolved and beetle species branched off to specialise in feeding on them. Scarab beetles emerged around 145 million years ago, at the start of the Cretaceous period. This was when New Zealand split from Australia and South America drifted away from Antarctica. Scarabs found themselves on all the main continents and the isolated populations continued to diversify to fill different niches. **LV**

There are over 30,000 known species of scarab beetle that come in all manner of sizes and colours

5-SECOND FACTS

The can opener was invented long after the tin can

Can openers came about nearly 50 years after the invention of the can itself! Before the introduction of the opener, cans were accessed by brute force alone, typically using a hammer and chisel. As canned foods went mainstream, a more practical device was called for.

The Sun is brighter than most other stars in our galaxy

Although we know there are some truly massive stars that are many, many times bigger than our Sun, the star in our Solar System is actually brighter than 85 per cent of them. This is because the majority of stars in the Milky Way are low-mass red dwarfs nearing the end of their lives.

How does Google Glass work?

Jason Parks

■ Google Glass brings all of the functionality of a smartphone to a lightweight pair of glasses. The concept is called augmented reality. Looking through the head-mounted display, you see your normal world, but also a small high-definition screen in the upper-right corner of your vision. While wearing Google Glass, you can use voice commands and gestures to take photos and videos of what you are seeing, launch a Google Hangout (video chat) with friends, conduct a Google search, get directions, chat using voice-to-text and even translate a conversation in real-time. Google Glass won't be released to the public until 2014, but developers have already created apps to provide hands-free recipes in the kitchen and to browse headlines from *The New York Times*. **DR**

Who built the Millennium Clock Tower?

Sandy Travers

■ The Millennium Clock Tower is a ten-metre (33-foot)-high kinetic sculpture at the National Museum of Scotland, built in collaboration by artists Maggy Lenert, Tim Stead, Annica Sandström, Jurgen Tubbecke and Eduard Bersudsky. The wood, metal and glass sculpture commemorates the achievements and tragedies of the 20th century and has four sections. The crypt – at the bottom – is made up of wheels and chains with carved figures. Next is the nave where the most striking feature is a pendulum in the form of a convex mirror. Farther up is the belfry, which houses the clock and lastly above that is a wooden spire. **RS**

Has a shuttle's landing parachute ever failed?

Whitford Rees

■ Fortunately not – though the shuttle would probably have been fine even if it had. The Space Shuttle orbiters touched down at speeds of around 355 kilometres (220 miles) per hour – about 30 per cent faster than a jet airliner – and since it was effectively a giant glider, it didn't have engines that could be reversed to slow it down. Instead, the Shuttle initially relied on good old-fashioned tyre brakes and a lot of burnt rubber, with the 'parabrake' as an emergency fallback. After the 1986 Challenger disaster, a safety review recommended using a modified version of the parabrake on landing to increase stability and reduce wear on the tyres and brakes. The parabrake system, consisting of a 2.8-metre (nine-foot) pilot chute and a 12.2-metre (40-foot) main chute, was used successfully on 84 occasions. **GS**

Planets and their stars do affect each other's orbits, but the planet will always do more legwork in this relationship

Are there any stars that orbit planets?

Raphael Treccani-Chinelli

■ The official definition of a planet is an object of a certain size that forms in orbit around a star but isn't big enough to become a star itself, so (barring accidents) planets nearly always still orbit their more massive 'parent stars', and because the less massive object is usually said to orbit the heavier one, the planet always revolves around the star. However, there's a slight complication. In reality the two objects actually orbit around their shared 'centre of mass', or barycentre (normally well inside the star). Although the star isn't really revolving 'around' the planet, it is being pulled around by it, and the resulting 'wobbles' are one of the clues astronomers seek to discover new planets. **GS**

Can CPR break bones if done correctly?

John

■ CPR involves repeated chest compressions about five centimetres (two inches) deep, but doesn't always cause broken bones. About 30 per cent of patients undergoing CPR will end up with a fractured rib or, in four per cent of cases, a broken sternum. Some patients are more vulnerable than others – eg those with osteoporosis. The person performing the CPR also makes a difference: one study showed that laypeople are more likely to break ribs than doctors. In any case, fractured ribs are a small price to pay if the CPR saves a life. **AC**

Chest compressions and rescue breaths keep blood and oxygen circulating in the body

Should we let pandas die out naturally?

Monique Williams

■ No. Pandas are herbivorous animals descended from a long line of carnivores. As a consequence their teeth and digestion aren't very well suited to their bamboo diet. They are solitary and reproduce slowly. They also don't play any especially important role in their ecosystems. But however irrational it is, we find pandas cute and they raise a lot more money as a flagship conservation species than we spend on protecting them. Concern for pandas also helps the many other unique species that live in the same Chinese forests. It isn't so much about the value of the pandas themselves as the wider cause they represent. Pandas might or might not eventually die out anyway through 'natural causes', but let's not kid ourselves: the reason they are endangered now is because of human encroachment on their habitat. **LV**

New Brain Dump lands

■ That's right, folks, the latest issue of Imagine's awesome digital-only science magazine is available on Apple Newsstand's virtual shelves right now for your delectation. Jam-packed full of fascinating facts and incredible illustrations, issue three of **Brain Dump** offers snappy, authoritative answers to a plethora of everyday quandaries that have had many of us scratching our heads at some stage. Ever wondered why penguins' feet don't freeze on the Antarctic ice? What about why rain clouds are darker than normal ones? Or have you pondered whether it will ever be possible for humans to colonise Mars? Well, for the answers to these and many more, download the latest issue of **Brain Dump**, your essential monthly fact fix. And don't forget to check out the mag's Facebook page at **www.facebook.com/BraindumpMag** or to follow @BrainDumpMag in the Twitterverse.

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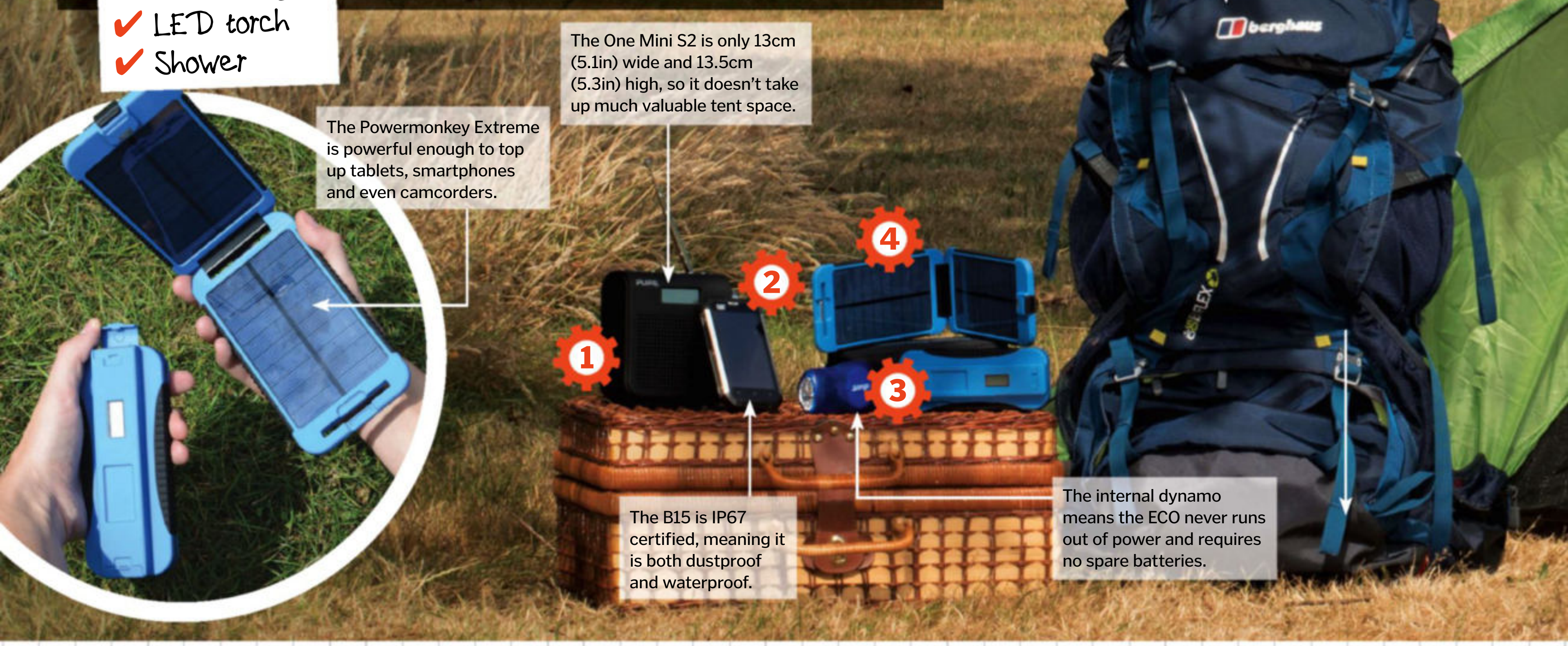
Festival season

The kit you need to get the most out of a festival

Checklist
- Tent
- Sleeping bag
- Rucksack
- Smartphone
- Digital radio
- Solar charger
- LED torch
- Shower

With the warm weather arriving just in time for the hectic festival season, now is a better time than any to make sure your camping gear is in order. After all, attending a festival poorly prepared is a sure-fire recipe for disaster. This issue, we have assembled a mixture of the best high-end and low-end camping products on the market, covering most of the key kit. As you'll see, you may be living in a field for a few days, but that doesn't mean you have to sacrifice all your home comforts…



1 DAB digital audio

PURE One Mini Series 2
£49.99/$N/A
www.pure.com

Perfect for keeping the music playing even when the stages are empty, the PURE One Mini S2 is the latest addition to the company's great portable digital DAB and FM radio range. It is compact – measuring just 13 centimetres (5.1 inches) wide and 13.5 centimetres (5.3 inches) high – and comes loaded with ports for connecting iPods and MP3 players, offering good sound quality for its size. Costing just shy of £50, the One Mini is a fantastic all-round radio. With this Series 2 overhaul also delivering a more aesthetically pleasing design and soft rubberised finish this item comes very easy to recommend.

Verdict:

2 Tough phone

CAT B15 smartphone
£299.99/$430
www.amazon.com

Got the latest iPhone? Don't want to risk breaking it at a rowdy festival? Well, the CAT B15, a dual-SIM beast of a smartphone, has been designed to be tough. Aside from the super-strong Gorilla Glass screen, the B15 is also waterproof up to a metre (3.3 feet) for 30 minutes, drop-proof from up to 1.8 metres (5.9 feet), impervious to dust and fully operational up to 55 degrees Celsius (131 degrees Fahrenheit). Like all CAT products, this phone is built to be outdoors. Plus, with the B15 running the latest version of Android – 4.1 Jelly Bean – it is also rich with software features. The only real downside is the price.

Verdict:

3 Dynamo lighting

Vango ECO Press LED torch
£4.50/$N/A
www.outdoormegastore.co.uk

Very handy for those middle-of-the-night trips to the communal toilets, the ECO Press LED torch is a battery-free, handheld flashlight which is both activated and powered by a simple trigger action. By repeatedly squeezing the torch's case-mounted trigger, the internal battery is supplied with charge via a dynamo, with approximately one minute of squeezing equating to three minutes of illumination from the LEDs. There is an on/off button too, meaning that charge can be stored for later and used when needed, and the trigger can also be removed and locked inside the case for easier handling.

Verdict:

4 Solar power

Powermonkey Extreme
£120/$179.99
www.powertraveller.com

Camping isn't what it used to be, with the modern festivalgoer laden with power-hungry technology. Help is at hand in the form of the Powermonkey Extreme solar charger, a device capable of charging myriad devices via the power of the Sun. The system consists of a 9,000mAh battery and solar panel, which – together – enable you to harvest those sunrays and then direct their power into your gadget through either a five-volt USB socket or a 12-volt DC port. This versatility is most welcome, allowing everything from SLR cameras through to portable DVD players and tablets to be topped up.

Verdict:

EXTRAS

Some essential resources to get you through that summer festival

BOOK

The Cool Camping Guide To Festivals

Price: £21/$37
Get it from: www.amazon.com
Author Sam Pow delivers a decent overview of 50 of Europe's most influential and popular festivals in this title, offering advice to get the most out of them. Each festival receives its own review and makes other recommendations based on the reader's preferences.

APP

Festival Ready

Price: Free
Get it from: Google Play/iTunes
A tidy little free app from the makers of the Swiss army knife, Victorinox, Festival Ready delivers 3D navigation, a torch, a packing checklist, a range of camping tips and a live weather updater. Login comes via Facebook integration, which is handy for finding your mates amid the crowds.

WEBSITE

efestivals.co.uk

A rough-and-ready website with a messy interface hides a treasure trove of information on all things festival, ranging from lineups to travel guides and ticket purchasing. Many UK festivals are also reviewed on the site, with brief synopses introducing the character of each as well as outlining their history.

5 Dynamic support

Berghaus Bioflex 50+10 rucksack
£160/$N/A
berghaus.com
If there's one thing you should splash out on when camping it's a rucksack; after all, it is often the gatekeeper to all of your other equipment. This is something Berghaus has realised when creating the Bioflex 50+10 rucksack, with a focus on storage capacity, accessibility and protection. The real star here though is the Bioflex system – a dynamic support structure mounted to the back that helps transfer the bag's weight which adjusts to each individual. This makes for super-comfortable carrying over long distances and difficult terrain – perfect if there's a bit of a hike to reach the festival site.
Verdict:

6 Portable shower

Solar-heated shower
£3.20/$N/A
kingfisher-online.co.uk
Music festivals have a reputation for getting messy – especially in muddy Britain. This Sun-powered camping shower is a large, black PVC bag capable of holding about 20 litres (5.3 gallons) of water. When exposed to sunlight, the water within is heated to a toasty temperature. This water can then be siphoned off through a hose with an attached shower head, providing a welcome, if low-power, shower. It's simple, cheap and much better than being covered in mud – or worse – until you get home. Of course, this shower loses its appeal somewhat if the Sun doesn't make an appearance!
Verdict:

7 Hydrostatic fabric

North Gear Mono two-man tent
£35.99/$N/A
www.thesportshq.com
Festival tents tend to be cheap and cheerful, lasting only a season or two. And to an extent, the North Gear Mono falls into this category, but made as it is from North Gear's 190T waterproof hydrostatic fabric, and with a sealable canopy, air vent and mesh door, it offers a bit more than the standard. The actual sleeping area is 1.5 metres (4.9 feet) wide and just over two metres (6.6 feet) in length, with the canopied entrance adding an extra 0.9 metres (three feet). Pitching is straightforward too – which is much appreciated when you don't want to miss out on any music and the beer starts flowing…
Verdict:

8 Hollow fibres

Kissing Stags sleeping bag
£60/$N/A
www.theglamcampingcompany.com
Now this is just a lovely sleeping bag and, what's better, it comes in two distinctive designs – both made from 100 per cent printed cotton. The one on show is the Kissing Stags offering, while a Kissing Rabbits one is also available. The bag itself has an old-fashioned non-tapered shape – ie it doesn't get narrower at the feet end. It's machine washable and has a filling of hollow fibres for extra heat and comfort. The bag also comes with a matching design roll-up sleeve to keep it clean. Warm, stylish and not too heavy at 740 grams (26 ounces), this bedding will certainly be a talking point if nothing else.
Verdict:

Gaming mice

We pit four high-precision peripherals head to head to see which comes out on top…

1 Razer Ouroboros

Price: £129.99/$TBA
Get it from: www.razerzone.com
Okay, let's just get the price thing out of the way. Yes, the Razer Ouroboros is a penny shy of £130. That is, without doubt, a lot of money for a mouse – even if it is a high-end peripheral aimed at serious gamers.

That said, technically the Ouroboros is the most advanced mouse in this roundup by far, with an amazing 8,200 dots per inch (dpi) 4G Dual Sensor System delivering fantastic tracking and excellent sensitivity for any game or application. What's more, the mouse is wireless – making it unique in this test – and with a one-millisecond wireless response time, we experienced no noticeable lag whatsoever.

On top of this the Ouroboros brings a nuanced modification system to its outer shell, so users can interchange various panels and adjust its overall length and width for ultimate comfort. The shell itself has been designed to be ambidextrous too, allowing easy right- and left-handed operation.

As you would expect with a Razer product, the Ouroboros can be customised with a variety of software profiles, with Razer's Synapse 2.0 technology capable of storing and syncing them to any machine via the cloud. It's pricey, but if you're a tech junkie like us, you'll fall in love with this.
Verdict:

Tracking tech
The Ouroboros's high tracking accuracy comes courtesy of a 4G sensor system, which is a combination of a traditional laser sensor and an optical one. The two sensors work together to ensure that positional awareness is maintained even if the mouse is briefly lifted up.

Powerful processor
The various functionality offered in the Naos – ranging from its 8,200 dpi sensor to its LED lighting system – works as it is controlled by an internal 32-bit ARM processor running at 72MHz. Building in this hardware also allows things like sensor sensitivity switching to be instigated on the fly.

Solid aluminium
The high movement accuracy of the M60 is largely thanks to its unibody aluminium frame build. Aluminium is both very rigid and low weight, meaning there is little unwanted movement when the M60 is in motion, granting improved accuracy – something that's crucial in, say, an FPS game.

It may look like something out of *TRON*, but the Ouroboros is surprisingly comfortable to use

Razer's Ouroboros is powered by a single AA battery – said to be good for 12 hours of gaming.

You can really bring some personality to the Naos 8200 with several million LED light colour options

2 Mionix Naos 8200

Price: £69.95/$89.99
Get it from: mionix.net

Forming in 2007, Mionix is a relative newcomer to the gaming peripheral market. That didn't stop it making a great gaming mouse though, with the Naos 8200 delivering fantastic all-round performance.

Technically it is excellent. An 8,200 dpi laser is partnered with 128KB of internal memory, a 32-bit ARM processor running at 72MHz and a variable polling rate that can be tuned up to 1,000Hz. In terms of build quality the Naos also scores highly, with seven programmable buttons well spaced over its rubber-coated body – granting the mouse a soft tactile touch and secure grip.

Customisation is also a focus, with the ability to adjust its LED lighting system – including pulsating, flashing and blinking patterns – and up to five separate profiles can be stored. Indeed, the only area in terms of customisation that the Naos doesn't deliver on is an adjustable weight system.

The Naos – while costly – is arguably good value for the technology delivered, with it coming in at just over the other wired mice in this group test.

Verdict:

Sensor science
The high sensitivity achievable by the Sensei RAW is the result of its advanced ADNS-9500 sensor, which has a high 5,670 dpi (dots per inch) count. In mice, dpi scores indicate the number of steps the sensor will report per inch travelled, with higher scores therefore granting better movement accuracy.

3 SteelSeries Sensei RAW

Price: £47.99/$59.99
Get it from: steelseries.com

Despite being the cheapest mouse on test, the SteelSeries Sensei RAW is a slick update to arguably *the* mouse of last year: the SteelSeries Sensei.

So what does it bring to the table? Well, aside from a few high-end features on the original Sensei – such as LCD display and customisable LED lights – the RAW offers equally impressive performance, largely thanks to the mouse's sensor. This is the same sensor that delivered 12,000 frames per second and a maximum acceleration of 30 g in the original and, as you would expect, it remains fantastic, offering excellent precision across a wide range of games.

What is new with the RAW is its soft, rubberised body, which offers excellent grip across all handling styles – eg palm, claw, swipe, etc – as well as a great ergonomic quality that is absent in many plastic-shell mice selling around the same price point.

Throw in eight well-designed buttons, a fast and responsive scrollwheel and a sensor responsiveness switch – ideal for moving from twitch shooters to slower-paced, real-time strategy games – and it's not hard to recommend the Sensei RAW.

Verdict:

4 Corsair Vengeance M60

Price: £54.95/$69.99
Get it from: www.corsair.com

A really solid all-round entry from Corsair, the Vengeance M60 Laser Gaming Mouse features a bunch of tasty tech for a modest price.

The M60 is designed primarily for FPS (first-person shooter) games, but after using it to play a variety of titles – including slower-paced games such as *Dota 2* – we found the M60 to be more than up to the job. That is no doubt down to the Avago ADNS-9500 sensor, which offers a precision of 5,700 dpi.

It's not just the sensor though; the aluminium unibody frame also contributes to the M60's stellar performance, offering super rigidity in use. In fact, of all the mice in the group test the M60's build quality really stands out, with a solid, no-nonsense, metal-heavy design granting confidence when in the palm.

In terms of extra tricks, the most notable is the 'sniper button', which lowers the mouse's dpi on the fly to allow for more control during precise shooting; it's a nice addition, but hardly a game-changer.

Overall the M60 is a very good gaming mouse and, as one of the more reasonable here, is well worth considering if you're in the market for a peripheral.

Verdict:

ON THE HORIZON

We highlight four other items to look out for in the near future

PlayStation 4

The new PlayStation (PS4) came out of E3 much better than the Xbox One, with many visitors wowed by its games and advanced hardware. Whether or not Sony can improve its online PlayStation Network, however, will only become evident when the console launches in November.

Nexus 7 (second generation)

The original Nexus 7 established that 17.8-centimetre (seven-inch) tablets were both feasible and popular, with the device selling very well for Google. Now over a year later the second iteration is set to bring a host of improved tech, including a 1,920 x 1,200, 320 ppi (pixels per inch) hi-def display and a speedy 1.5GHz Snapdragon S4 Pro processor. The iPad family better watch out!

Google Glass

With a select few technophiles currently trial-running Google's latest invention, and with interesting results too, it surely only has to be a matter of time before they go on sale to the public. The glasses superimpose information before the wearer's eyes, augmented reality style, and – provided they get mainstream support – could be the next big thing in tech. Right now though, reports indicate potential rather than a good-to-go product that's ready for the mass market.

Kinect 2.0

Despite receiving a bit of flak from the critics at this year's E3, Microsoft did at least show off some of the advanced capabilities of its second-generation Kinect motion-tracking system, which seems to be a vast improvement over the original. Of course, until the Xbox One launches toward the end of the year, we will have to wait and see whether the accuracy will deliver fail-proof hands-free gaming.

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How It Works magazine @HowItWorksmag

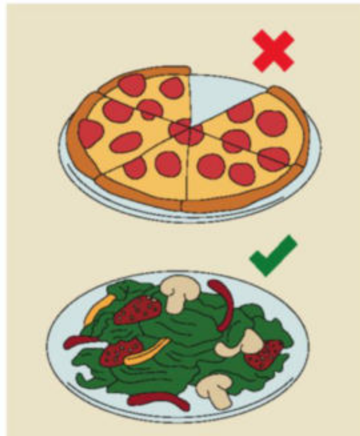
howitworks@imagine-publishing.co.uk

Run a marathon

Stay fit, raise money and improve self-esteem, but don't forget to prepare...

1 Equipment

It's common sense, but it's surprising just how many people attempt long-distance running in inappropriate clothing. Baggy shorts may look cool, but after a mile or two they are going to start rubbing. Marathons are endurance events and you need clothes that can deal with that, so nylon or Lycra shorts are better. The same advice goes for your top. Light but supportive trainers are a must for serious runners too.



2 Diet

Diets can be as simple or as complicated as you want, but there are certain things you should be eating to fuel your body. Eggs, nuts, sweet potatoes, wholegrain cereals, salad, fish, fruit and low-fat yoghurts are all excellent, while high-fat/high-sugar choices such as fried food, cheese and bacon are to be avoided. Coffee – while delivering caffeine – is a strong diuretic and should only be drunk in moderation before a run.

3 Physical training

It's amazing how many people think they can just rock up to run 42 kilometres (26 miles) without any practice. They are wrong. At least three months before the marathon begin a running regime and slowly build up distance and speed. If you live near to where the event will be held, run parts of the course – this will help flag any particularly tricky areas and lend a sense of familiarity when the day of the marathon comes around.

4 Mental training

During a marathon it's important to remain mentally strong – this can be the difference between crossing the finish line or not. First, run to your own ability at all times; remember it is about pacing yourself more than speed. Second, get into the habit of breaking down the run into a series of smaller segments as this will help deliver short-term goals. Finally, try to remain as calm as possible to conserve energy.

5 On the day

When it comes to the actual marathon day, the most crucial thing you must do is trust your training. If you have prepared properly then, regardless of the many miles that lie before you, you will make the finish line. When actually running, aim to maintain a steady and comfortable speed. Try to ignore distractions – including family members, keep your eyes fixed ahead to avoid injuries, and stay positive; focus on *why* you're running the race – especially in the final third.

Disclaimer: Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced when carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

In summary...

Most people can run a full marathon provided they have the appropriate apparel and training. Being as physically fit as you can be is obviously important, but maintaining the right mindset is in some ways more crucial. If you respect the challenge of running just over 42 kilometres (26 miles) and prepare properly, then there's little doubt you will succeed.

Learn more

To get off on the right foot with your running, be sure to check out the **Running for Beginners** bookazine available from **www.imagineshop.co.uk**.

NEXT ISSUE
- Plaster a wall
- Hit a hole in one

Blend a smoothie

Got fruit, ice and a blender? Then you can make a smoothie as tasty as it is healthy

1 Fruit and ice

To start you need ice. If you have an ice machine at home then this part is easy – if not, then you need to manually crush some ice cubes. Don't ever put whole ice cubes in a blender as they can potentially damage it. Once the crushed ice is ready, add your fruit of choice. Again, try to break down or shred the fruit base before adding it to the ice as this will make the blending process easier and result in a smoother finish.

2 Juice and filler

Next it's time to add some juice. Fill a cup with any kind of fruit juice and pour it over the crushed ice and fruit puree. This will help to melt the ice and add extra flavour to the drink. If you like, at this point you can include a filler such as yoghurt or – if you're feeling more indulgent – cream. This will help to thicken the consistency of the smoothie, making it easier to pour, but this latter ingredient is optional.

3 Blend and drink

With all the ingredients in the blender, it's time to combine them. Crucially, don't be tempted to whack the blender to its fastest setting straight away. Instead, work your way up through the speed settings while watching the consistency, only blitzing on max speed at the end for a few seconds. If your blender doesn't have speed increments, use the pulse mode intermittently. Lastly, garnish the smoothie with fruit or a mint leaf.

In summary...

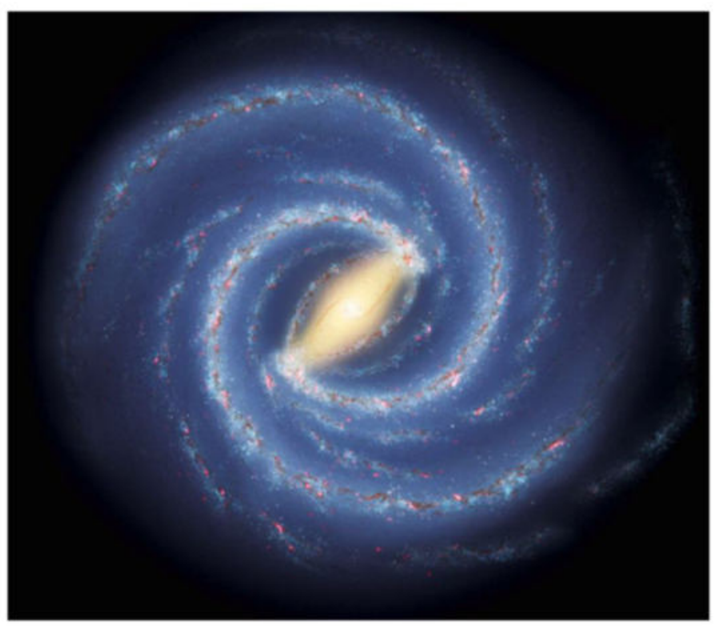
If you have a blender, ice and fruit then you have all you need to make a smoothie. Experiment with different fruits and build each smoothie from the base up, starting with ice and fruit chunks, then adding juice and fillers for a richer drink. Be patient with the final blending process.

QUICK QUIZ

Test your well-fed mind with ten questions based on this month's content and win a working model of a combustion engine!

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. How long does it take the Milky Way to make a complete turn on its axis?
2. In which country are the Waitomo Caves located?
3. How much of Antarctica is covered with ice?
4. In which year did Nikola Tesla publicly show wireless electricity for the first time?
5. How many species of toucan are there?
6. Who designed New York's Brooklyn Bridge?
7. How high did ash from the 1883 eruption of Mount Krakatoa reach?
8. The tin can was invented in 1810, but in which year was the can opener invented?
9. How long was the historic Silk Road through Asia?
10. In which year was the Luna 1 space probe launched?



© NASA

ISSUE 49 ANSWERS

1. 8 hours **2.** Ricin **3.** 400km/sec **4.** Formula Rossa **5.** 9%
6. Arctic tern **7.** 1622 **8.** 638km/h **9.** 20,000mn **10.** 2,100km/h

INBOX
Speak your mind...

Get in touch

Want to see your letters on this page? Send them to...

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howitworks@imagine-publishing.co.uk

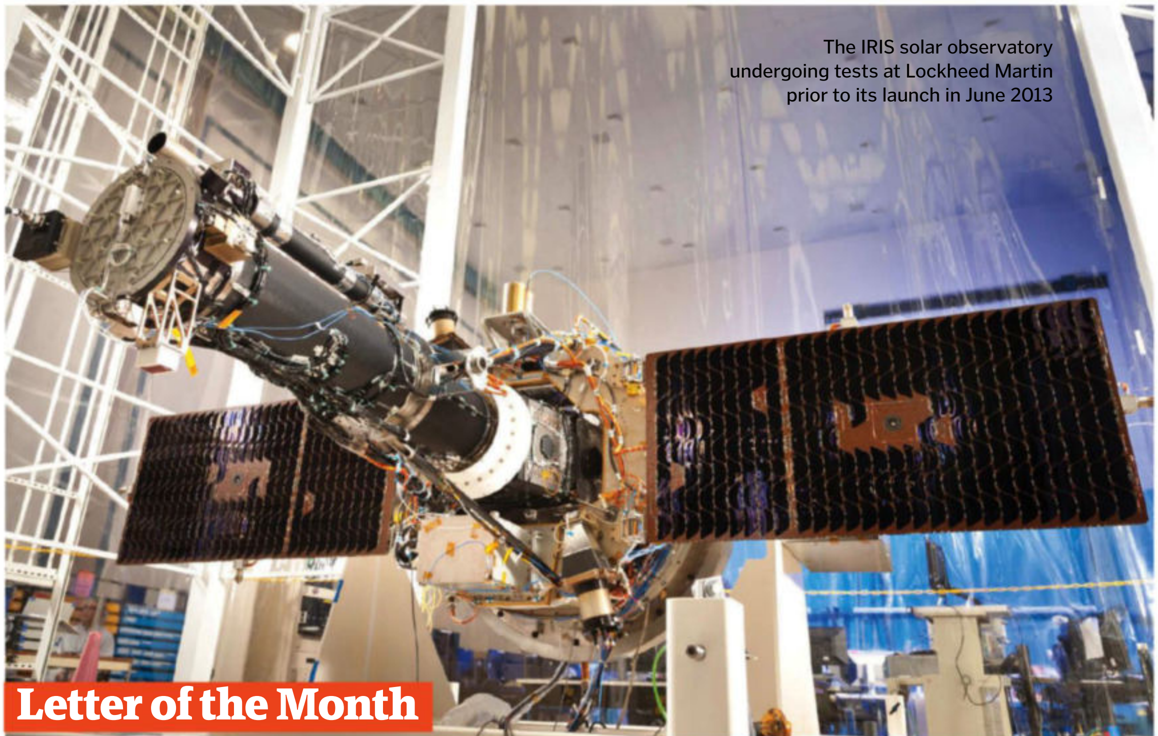
WIN!

We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!

WIN YOUR VERY OWN STARTER TELESCOPE!

The writer of next issue's 'star' letter will win themselves a Visionary FirstView Starter Telescope. Visit www.howitworksdaily.com for details.



The IRIS solar observatory undergoing tests at Lockheed Martin prior to its launch in June 2013

Letter of the Month

Brainiac aims for the stars

Dear HIW,
Your wonderful magazine brings to life science and sparked my interest in the field of physics and chemistry in particular. It's so exciting to learn something interesting and the illustrations inspire me to do further research.

Something else that inspired me was witnessing the launch of NASA's Interface Region Imaging Spectrograph (IRIS) mission to monitor the Sun and its chromosphere. I had never watched a live launch in my life, so from there I started looking up into the sky with my telescope and writing down my observations.

I read all your issues and you clearly put a lot of effort into making these articles easy to understand. Trying to get younger people into science is not an easy thing to do, but thanks to your great illustrations and information science will become a more favourable subject for all ages.

This opportunity to see *Brainiac Live!* is a young scientist's dream: doing quirky experiments and blowing things up! This will hopefully push me where no man has gone before – to think of things not even Einstein could think of.
James Tantrum (15)

Thanks for your very enthusiastic letter, James. We had to award you Letter of the Month not only because you sound like a *Brainiac* superfan but also because your love of science shone through. We had to cut your letter down a bit as it was rather long, but it's evident you're an aspiring science pro. Good luck and here's hoping you'll turn out to be the Albert Einstein of the 21st century. We hope you enjoyed the *Brainiac Live!* event which was our exclusive prize for issue 50 and you'll have seen by now.

The truth about batteries

Amazing magazine that never fails to deliver. I devour it from cover to cover. In issue 47 reader Robert Philipson asks for an answer as to why his iPod has lost its maximum battery life over time and wonders why this happens in general to electronic devices.

He may be interested to know that iPod batteries are manufactured to fail after about 500 charges and are attached to the iPod casing so they cannot be changed easily or cheaply. This so annoyed a group of formerly happy customers that in 2003 they took Apple to court to open a collective case against the company. However, Apple eventually reached a settlement with the plaintiffs including extended warranties.

As to why this happens to electronic devices? Often the cost of replacing the battery, or other single non-working part, is roughly the same as purchasing a new model and this was certainly true in the above case. It's a key selling strategy on the part of manufacturers and is widely used in industries across the board.

And that is how that works.
Sincerely,
Delia Smith

We love it when readers write in to respond to other readers' questions and letters from previous issues, so thanks for getting in touch to shed some light on Robert's query, Delia. You're right, rechargeable batteries do only allow a limited number of charge cycles. Indeed, many manufacturers now offer advice on how to preserve battery life (ie the length of time a device will run before it needs to be recharged) – and thereby its overall life span (the total length of time the battery will last before it needs to be replaced). One interesting tip is to use your iPod regularly to keep the electrons inside the lithium battery moving. Heat can also dramatically impact battery life so removing the device from its case so it can 'breathe' when charging should help it last longer too.

Solving revolving problems

Something has bothered me for as long as Pluto was considered not a planet but a 'plutoid'. From what I have read, it's because it is not the most influential object of its orbit, which is one of the three qualifications required to be a planet. However, by the same idea, why are Neptune and Uranus planets, because they – again from what I have read – revolve around each other?
John Robertson

Uranus and Neptune do have a gravitational effect on one another, as do all the other planets. They don't, however, revolve around each other. Their orbital paths are about

> "There are many theories even the International Astronomical Union cannot yet agree upon"

10AU apart (Uranus orbits at 20AU, Neptune at 30AU) – so they're not even close! Uranus and Neptune are categorised as planets because, among other characteristics, they have 'cleared their orbital neighbourhoods' – that is, they are gravitationally dominant and no other objects of comparable size (except their moons) exist there. Pluto, meanwhile, hasn't cleared its orbital neighbourhood. That said, there are many contentious areas of planet classification and theories that even the International Astronomical Union cannot yet agree upon.

Leap of faith

I have recently read your article regarding the 'Incredible Story of Earth' and something has really perplexed me so I wonder if one of your geniuses could explain. Your article in issue 47 (page 13) states that the Earth orbits once every 365.256 solar days; the bit I find confusing is how this fits into leap years. The extra day we get every four years accounts for the 0.25 solar days, but how do we accommodate the 0.006? I've tried to Google it, but I can't seem to pull the right answer up (well, one that I can understand anyway).
Darryl Hough
PS I love the magazine!

The answer to this is way too long for the letters' page. But we do plan to write something on this in an upcoming issue. The long and short of it is that every year that is divisible by four is a leap year (one day is added on to February). However, there are many exceptions to account for the spare minutes and seconds – which would significantly affect the calendar over hundreds of years. Exceptions include the last year of each century that isn't a leap year; leap years when the number of the century is a multiple of four; and the year 4000 and its multiples (8000, 12000, etc) which aren't leap years. Yeah, this topic definitely warrants its own article, doesn't it?

Too much boys and their toys?

I took out a subscription to How It Works as I was hoping it would encourage my 13-year-old daughter to become more interested in science. She is good at physics and biology but wasn't excited by science really. Unfortunately, both she and I feel that the magazine is aimed much more at boys. There are definitely interesting articles in HIW, but dads and brothers seem more engaged by the topics covered than the female members of my household. (That includes me, a female doctor, who is genuinely fascinated by science.) New discoveries and inventions are interesting, simple explanations of common medical conditions are fine, Q&As from readers are useful, but there are too many items on space, missiles, trucks, etc. But hey, that's just my opinion – other readers may love it all!
Vaseem

Vaseem, thanks for this feedback. We work hard to ensure the magazine is universally interesting and appealing – visually, editorially and in terms of the topics covered – so it's a shame you and your daughter don't feel the magazine has enough to hold the interest of a female reader. We take your comments seriously because, as science educators, we feel it's our responsibility to work together with the rest of the community to encourage those who may have less of a natural interest in science and technology to actually take a look and discover how incredible things work. If there are any topics you'd like to see more/less of in How It Works we'd love to hear from all our readers.

As the first American woman to go to space in June 1983, Sally Ride made a great leap for female scientists

What's happening on... Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month...

ImAdamTM @ImAdamTM
@HowItWorksmag. Forget the big questions, what I'd like to know is how I always seem to end up with stones in my shoes!

Vi @I_Miss_You_Gee
@HowItWorksmag Just got the latest issue, what a great magazine! I loved the detail on the DNA section – well done!

Nader Shakhshir @ NaderShakhshir
@HowItWorksmag. Thank you, guys, for this awesome magazine! I found an annual in my university's library and I was astonished by it

Scott Myers @ScottMyers19
Just subscribed to **@HowItWorksmag** :D

Alex Craven @jojoaljojo12
@HowItWorksmag Love the magazine. Only just started buying it but love it all the same. When will the next issue be out?

Oliver Lisney @oliverlisney
@HowItWorksmag
Why do some sounds sound good to us and others don't?

Lee Sutton @Lee_1609
@HowItWorksmag
Received my Supertooth speaker today – it's brilliant! Thanks again, How It Works & Imagine Publishing!

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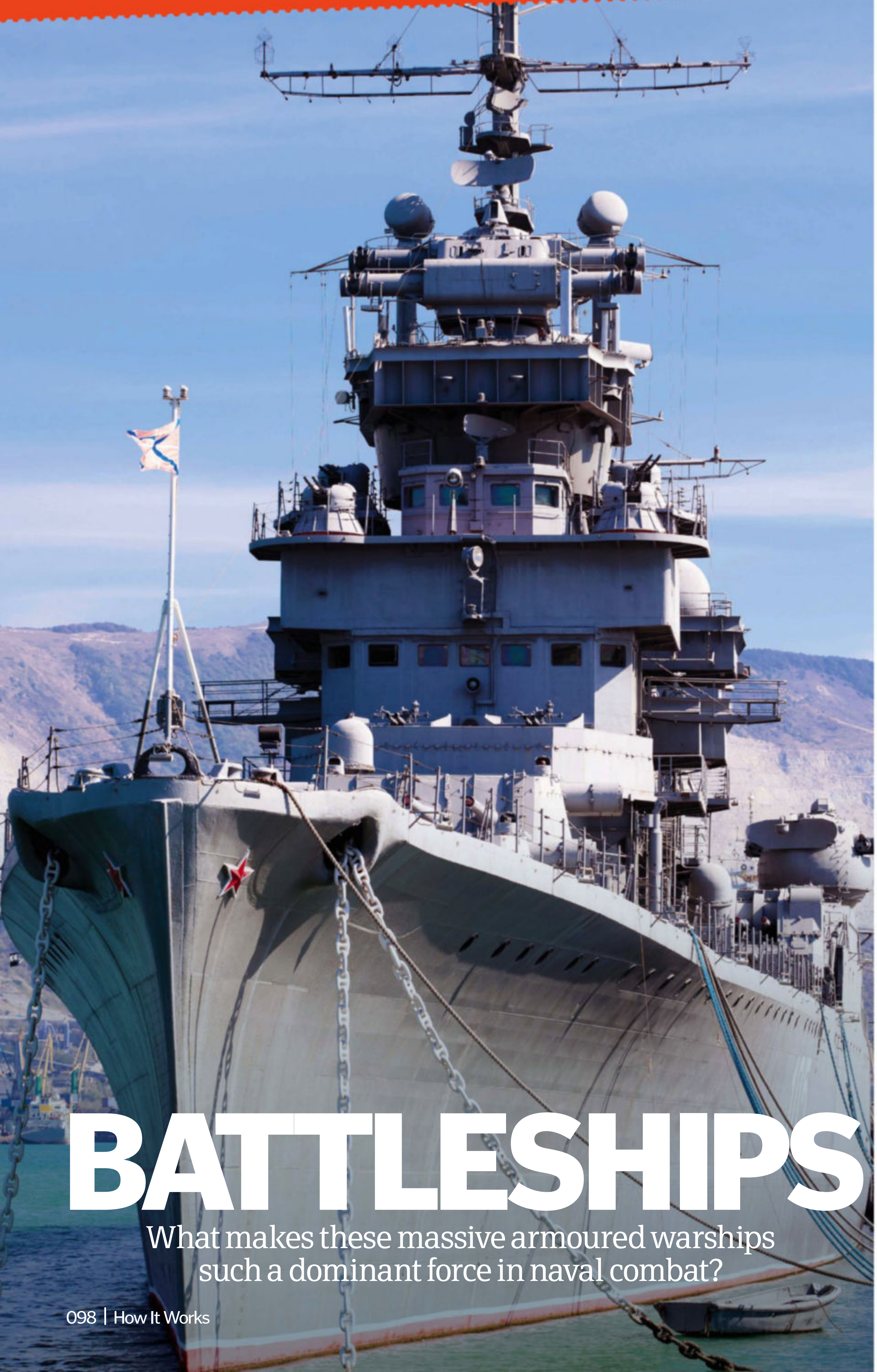


BATTLESHIPS

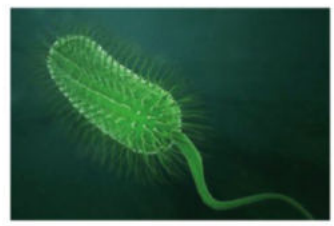
What makes these massive armoured warships such a dominant force in naval combat?

ANSWERED NEXT ISSUE

How was the American Civil War fought?

How do we use science to date old artefacts?

Why is the ESA heading to Jupiter and its moons?



What is the structure of a bacterium?

How do Earth's biggest animals survive?

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